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Methods for Estimating Orchard Mite Populations, Especially with the Mite Brushing Machine[1]

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Phytophagous orchard mites have become so troublesome in British Columbia during the last decade that special attention has been given to studies on their ecology and control. An important prerequisite for such studies is an accurate and rapid method of estimating population densities of both the mites and their predators. As some mites are less than a fifth of a millimetre long, it is difficult to determine the numbers of adults present on foliage, quite apart from the eggs and other immature stages.

Methods for estimating orchard mite populations developed to date may be classified as either direct, in which the mites are counted on the leaves or estimated, or indirect, in which the mites are removed from the leaves and a known fraction is counted.

Direct Methods

Until recent years the most common method was to count all the mites on a sample of leaves with or without the aid of a hand-lens or a stereoscopic microscope, depending on the size and type of mite under study. Obviously, this procedure has many drawbacks. The method was improved upon by Hoskins, Boyce, and Lamiman (1938), who delineated, with a circular rubber stamp, five selected areas on each citrus leaf and counted thereon the number of the Pacific mite, *Eotetranychus pacificus* (McG.). The count-areas represented about 20 per cent of the leaf surface and contained approximately one-third of the mites present on each leaf. This procedure allowed the authors to examine a greater number of leaves in a given time. Baten and Hutson (1943) used a similar method, but instead of marking off areas on the leaf they inserted it between the halves of a piece of folded cardboard in each of which an opening one inch square had been cut. With the aid of a reading lens, they obtained an index of the population of the European red mite, *Metatetranychus ulmi* (Koch), on both the upper and lower surfaces of Delicious apple leaves. These methods are feasible only for low populations of readily visible mites; they are impractical for large populations unless the creatures are made immobile by anaesthetization or refrigeration.

Because of these disadvantages and certain peculiar habits of the Pacific mite, Newcomer (1943) developed an estimation procedure that proved useful for judging the abundance of mites on trees that had been sprayed to control the codling moth, *Carpocapsa pomonella* (L.). He examined each tree visually, noting the amount of webbing, the occurrence of injured leaves, and the relative number of mites. A number was then arbitrarily assigned to the degree of infestation on each tree. Variations of this method can often be used to advantage when assessing the value of acaricides in the field, but considerable experience is required.

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Indirect Methods

Four indirect methods have been employed for estimating mite populations on foliage. These are (1) the paper-impression procedure, (2) the removal of mites with solutions and subsequent aliquoting, (3) the beating of mites from twigs and foliage, and (4) the brushing of mites from leaves and subsequent counting of a fraction of them.

Paper-Impression Method

The paper-impression, or imprint, method was developed in Canada by Venables and Dennys (1941), and improved upon in England by Austin and Massee (1947). It has been used extensively by many workers and in England is still the method most commonly applied. The equipment is simple and cheap, consisting of a clothes wringer (mangle) and white mimeograph paper. The leaves are placed between the halves of a folded sheet of paper and passed through the rollers of the wringer. The mites and the eggs are crushed and usually leave identifiable stains on the paper. Insects, particularly aphids, likewise produce imprints but these are easily distinguished from those made by the mites.

This method has several advantages: it can be employed in the field; many records can be made in a short time; the semi-perament imprints can be stored and examined later at leisure; populations of mites on each side of the leaf are represented in the impressions.

Some disadvantages are as follows: (1) the method can be used only for recording populations of mites that leave readily visible stains on the paper; imprints of pale, yellowish-green species such as the Pacific mite and other tetranychids are difficult to see; (2) it is practically impossible to separate the various active stages of the mites; occasionally the stains of old, mature females can be distinguished; (3) a number of predacious mites, likewise nearly colourless, do not leave readily visible stains on the paper; thus the method cannot be used for biological studies involving the interrelations of predacious and phytophagous mites; (4) eggs and active mites frequently occur under a deep vein or more commonly a mid-rib, and when they are squashed their imprints do not appear on the paper; this error may be constant within any one plant variety but it may vary between varieties because of differences in the external morphology of the leaf; (5) after the mite impressions have been obtained, much time and labour are involved in counting the imprints, although this work can be reduced considerably by estimating the number of imprints rather than by making a direct count; in one trial, for example, the mite imprints from 1,300 leaves were estimated to represent an average of 22.7 mites per leaf and the actual number was 22.8.

The method is best suited for the European red mite and the clover mite, *Bryobia praetiosa* Koch. The crushed eggs of these mites impart small pinkish stains to the paper and can be distinguished without great difficulty from the stains of immature and adult mites.

Removal by Solutions

The densities of mite populations may also be measured by removing the mites from the leaves with solutions and aliquoting. This procedure was suggested by Jones and Prendergast (1937), who used it to estimate populations of the citrus red mite, *Paratetranychus citri* (McG.), on both leaves and fruits. These were stored in a five per cent formalin solution, and later were transferred to a 0.25 per cent heated solution of potassium hydroxide to remove the eggs. The plant material was then removed and the solution made up to a specific volume.

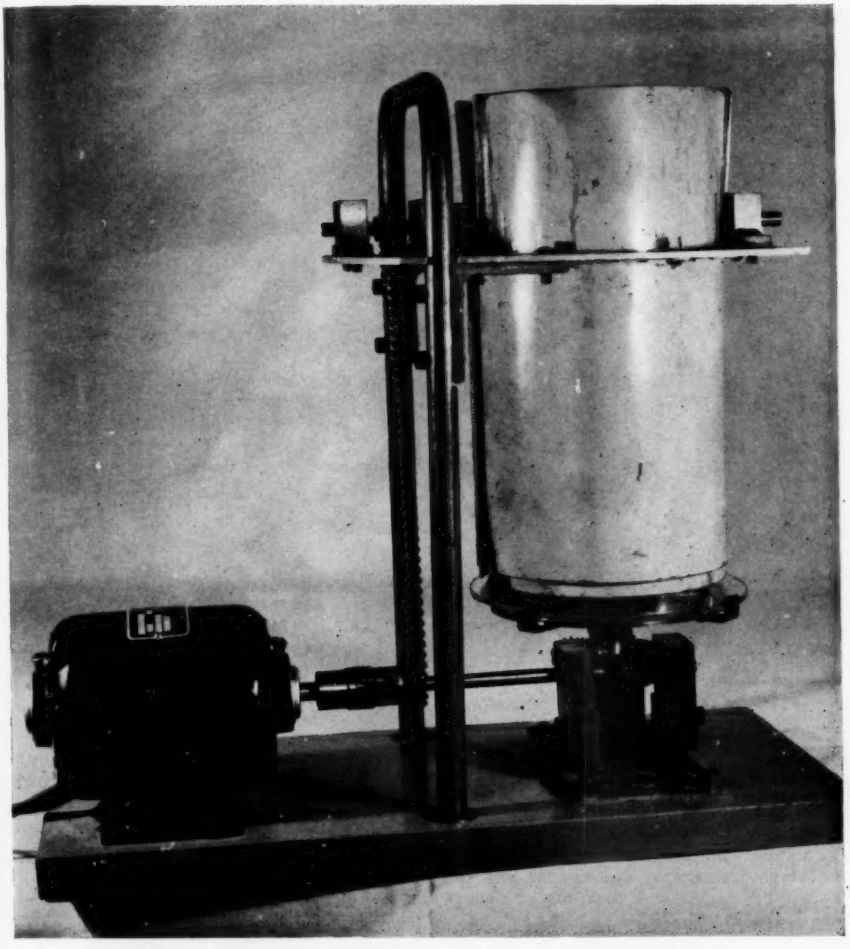

Fig. 1. The Henderson and McBurnie mite brushing machine.

While the mites and the eggs were maintained in a uniform suspension by mechanical agitation, an aliquot was drawn from the mixture and placed on a filter paper, where the mites were counted with the aid of a low-power, stereoscopic microscope. Newell (1947) used a similar method for determining the population density of the Pacific mite on apples, but he modified the procedure to suit the webbing characteristic of the mite and the relatively heavy pubescence of apple leaves. The mites were removed from the foliage by shaking the leaves in a container of monoethanolamine-oleate soap solution and rinsing them with a hard, needle spray. Then the sample was screened to remove the foreign material and the mite residue was washed into another container, to which more soap and water were added to bring the solution to a specified volume. Immediately after the solution had been stirred for 30 seconds, a known aliquot was taken into a test tube. The mites were allowed to settle and,

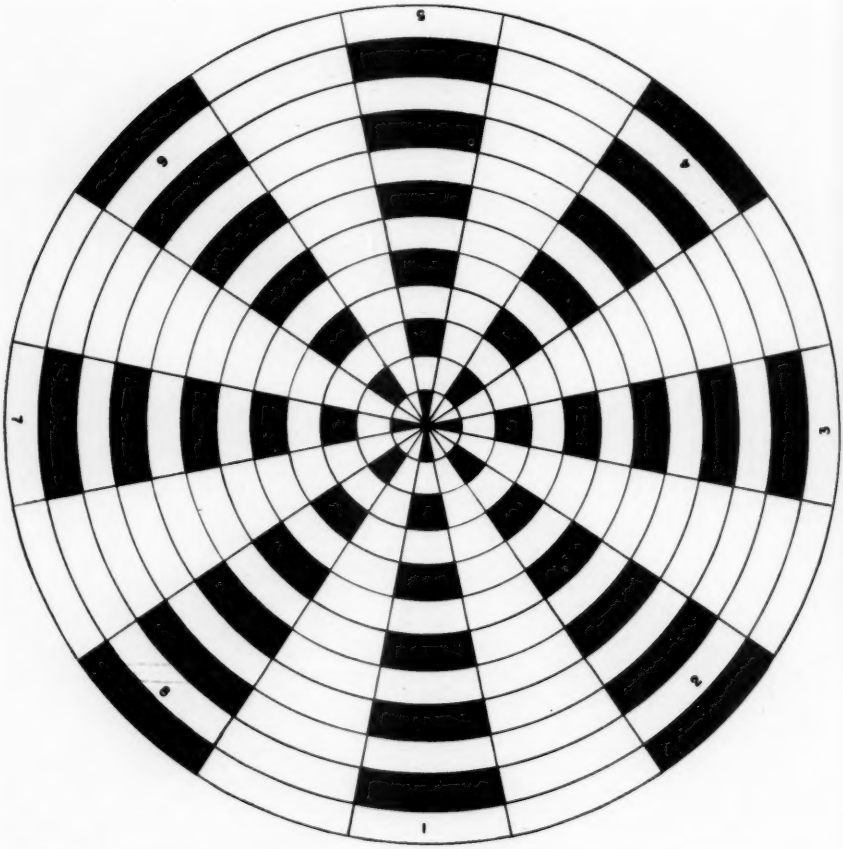

Fig. 2. Counting disk divided into 16 equal sectors and 12 annuli of equal width. Sections of equal width and unequal area.

after the supernatant fluid was siphoned off, they were transferred to a glass or plastic counting disk.

In 1949, the senior author and Mr. R. S. Downing of the Summerland laboratory developed a solution and aliquoting method for estimating the number of winter eggs of the European red mite and the clover mite on the aerial parts of the trees. Except in heavy infestations, practically all the winter eggs of these two mites are laid on the fruit spurs and in the axils of the spurs and the shoots. Consequently, the fruit spur plus a short piece of the shoot must be the sampling unit. The procedure is as follows: (1) soak the sampling units in benzene for about 30 minutes; (2) heat to almost boiling for 20 minutes; (3) vigorously stir the spurs in the benzene to remove the eggs; (4) remove the spurs and set aside to dry; (5) filter the cooled benzene solution through filter paper; (6) wash the residue into a beaker of water to which sodium lauryl sulphate has been added; (7) with the aid of a tube brush and a microscope, brush any eggs still on the spurs into a large petri dish and add these to the water and sodium lauryl

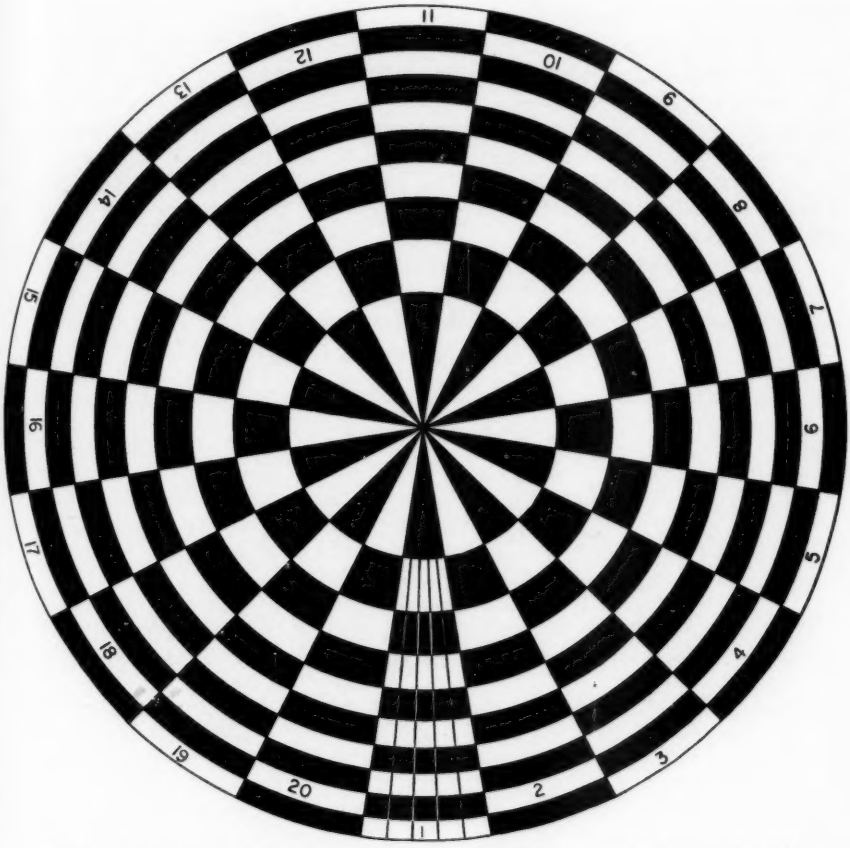

Fig. 3. Counting disk divided into 20 equal sectors and 10 annuli of unequal widths. Sections of unequal width and equal area.

sulphate solution; (8) bring the solution to a specified volume; (9) agitate the solution and draw off an aliquot into a pipette; (10) pipette the aliquot onto a filter paper placed in a filtering funnel; (11) spread out the filter paper and count the eggs before the paper dries. Eggs on dried filter paper are easily flicked off and lost. The addition of sodium lauryl sulphate or other suitable surface-active agent is necessary to reduce the surface tension of the water and thus prevent the eggs from adhering to the walls of the pipette and the beaker. The orifice of the pipette should be enlarged so that the flow of eggs will not be restricted. The density of eggs may be computed as the number per fruit spur or the number per unit area of fruit spur. In the latter case the surface area can be calculated from the formula $A = 3.54 \sqrt{VL}$, where A = area, V = volume, and L = length of the spurs. In 1950, investigators at the Entomology Laboratory, Harrow, Ontario, found that the eggs could be removed readily by soaking them overnight in a 1.5 per cent solution of sodium hypochlorite to which was added one drop of concentrated sodium lauryl sulphate per 25 millilitres of solution. An advantage of sodium hypochlorite over benzene is its non-inflammability.

Beating Twigs and Foliage

Most phytophagous and predacious mites live only on the foliage during the growing season and populations can be estimated simply by sampling the leaves. The clover mite, however, is one exception. It is found both on the foliage and on the woody parts of the tree and a true population index can be obtained only by sampling both leaves and twigs. This type of sampling can be accomplished by beating the twigs and the leaves over a wire rack (Summers and Baker, 1952). The method will be discussed below. It is applicable to other mites, particularly the European red mite.

Recently, Boudreaux (1953) described a rapid and simple beating method for collecting plant-inhabiting mites either for taxonomic purposes or for comparative population counts after acaricide treatments. The plant material is

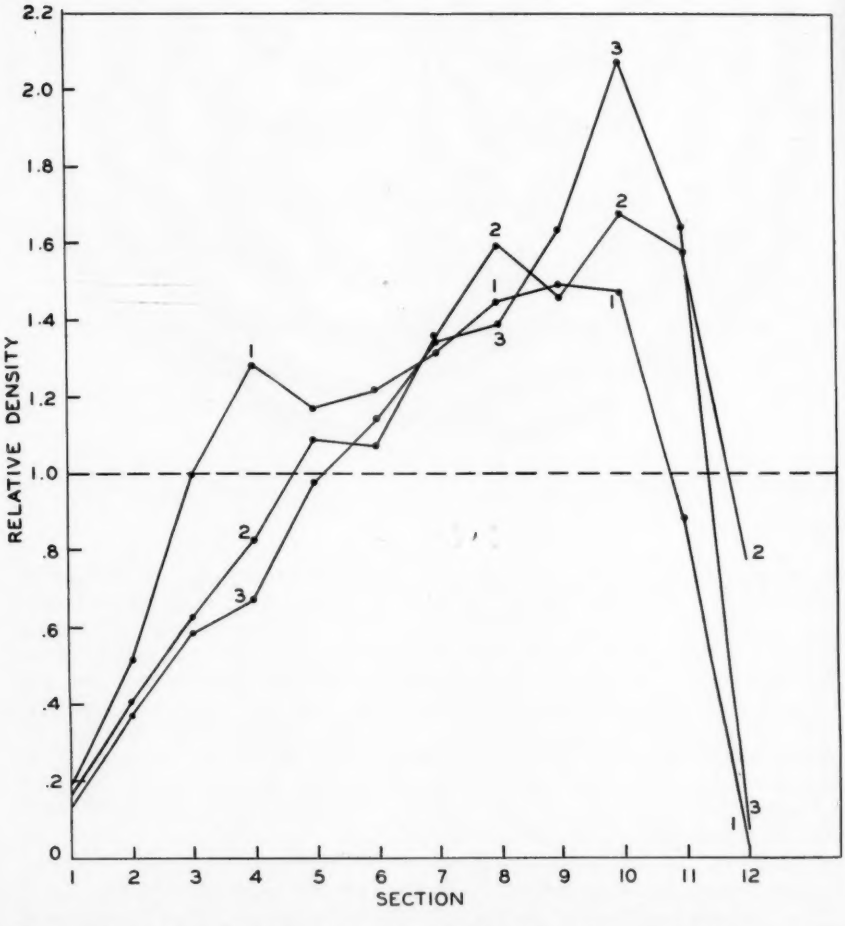

Fig. 4. Mean relative densities of the Euorpean red mite within sectors of three of the counting disks shown in Fig. 2. Section 1, apical section; 12, peripheral.

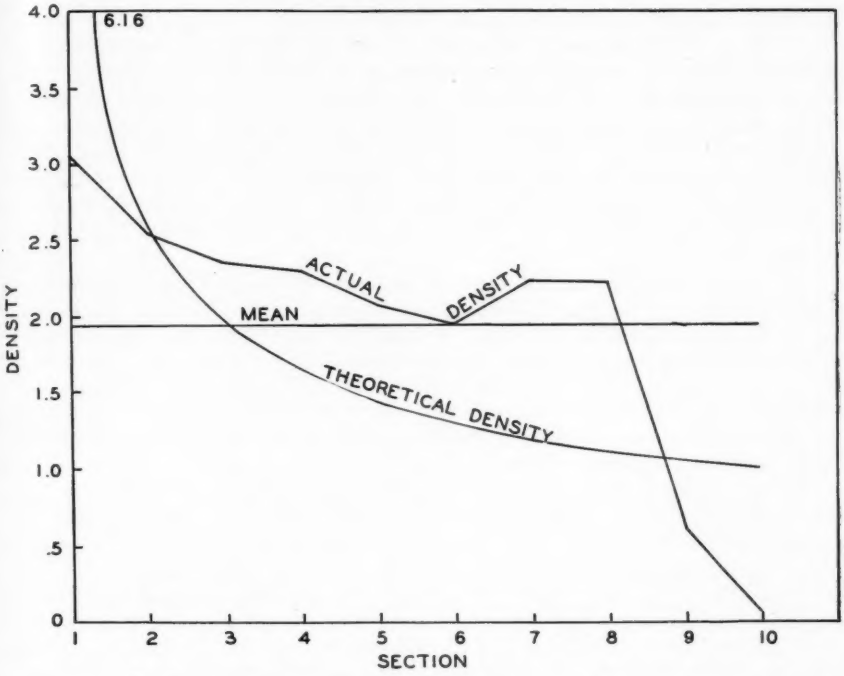

Fig. 5. Mean densities of the European red mite within sectors of five of the counting disks shown in Fig. 3. Section 1, apical section; 10, peripheral. Theoretical density of the n^{th} section, $D_n=6.16\ (\sqrt{n}-\sqrt{n-1})$.

beaten on a screen fastened over a funnel and the mites are collected in containers placed below the neck of the funnel.

The Mite Brushing Machine

The most satisfactory method for rapidly estimating phytophagous and predacious mite populations is a brushing machine (Fig. 1) developed by Henderson and McBurnie (1943), and manufactured by H. Gearing of California, U.S.A. Essentially the apparatus consists of a small electric motor that drives two contra-rotating spiral brushes and a turntable mounted about six inches below them. An adhesive-coated glass disk, five inches in diameter, is placed on the turntable to trap the mites. The machine is operated simply by inserting the leaf between the whirling brushes and withdrawing it; first one end of the leaf is brushed and then the other. To prevent the mites from being thrown out beyond the disk, a pair of curved metal slides extend about two inches above the brushes and down to within one-eighth of an inch of the revolving disk.

Henderson and McBurnie found that the machine removed 82 per cent of the eggs and 88 per cent of the active stages of the citrus red mite from orange foliage. The present authors found that 100 per cent of the active stages and 98.8 per cent of the eggs of the European red mite and of the clover mite were removed from the Delicious apple trees. Excellent results were obtained with

the yellow spider mite, *Eotetranychus carpini borealis* (Ewing), a tetranychid that spins a moderate amount of web. In one experiment, for example, every mite was removed from 100 leaves, averaging 15 mites per leaf. The machine has solved the problem of determining the population density of eriophyid mites. These mites are exceptionally small and one or two thousand are often found on a single leaf. Although difficult to see and count on the surface of a leaf, they are easily seen on the flat, clear surface of a glass disk. The performance of the machine varies according to the amount of overlap between the rotating brushes; a uniform overlap of about one-eighth of an inch from end to end of the brushes is ideal.

Excepting scale insects, the machine removes satisfactorily most insects and predacious mites. To test its efficiency in dealing with predacious mites, the eggs and active stages of *Mediolata terminalis* (Quale) and of *Typhlodromus rhenanus* (Oudms.) were counted on apple leaves with the aid of a low-power stereoscopic microscope. The leaves were brushed and then re-examined for specimens that had not been removed. In every case more eggs were counted on the glass disk than had been recorded on the leaves. None were found on the leaves after they had been brushed.

These results indicate that the brushing procedure is more efficient for estimating populations of phytophagous and predacious mites than microscopic examination of the leaves. The brushing procedure is particularly useful for estimating the density of mites when they are present in large numbers or when the species are particularly small. In addition, the procedure is rapid, and a large number of samples can be examined in a short time. Two workers, each operating a machine, can brush 50 samples of 10 leaves per sample in approximately 90 minutes. With the help of a third person to record the results, they can count the specimens on the disks in two to four hours, depending on the degree of infestation. Microscopic examination of the same number of leaves would take about two days, and would provide less accurate results.

An improvement has been made in the type of adhesive used on the glass disk. Originally the disks were painted with a thin coat of varnish or with a solution of 50 per cent varnish and 50 per cent benzene. After the counts, the varnish was removed by immersian in a hot, concentrated solution of trisodium phosphate followed by a rinse of hot water. This adhesive dries quickly and often becomes ineffective as a trapping agent. Also, if specimens are wanted for preservation, it is difficult to remove them from the varnish. A suitable adhesive should be colourless, should have a low surface tension, and should have a viscosity similar to that of varnish. It should remain in the liquid state for several days, and be easily removed from the disks. It should neither distort the mites nor decolourize them. The most suitable material so far examined as a trapping agent is a non-ionic, alkanolamine condensate, soapless detergent (Emcol 5100, The Emulsol Corporation, Chicago, Illinois). Since it has its greatest mobile viscosity at 12 per cent dissolved in water, it was used at this dilution. Not only is it an excellent trapping agent but it is also easily removed from the disk simply by rinsing in water. Another desirable feature is that mites trapped in this material are readily collected into vials of alcohol or chloral hydrate. When they are transferred to these solutions, they sink to the bottom of the vial instead of floating or adhering to the vial walls or the transferring needle as they often do in the normal collecting procedure. Mr. F. E. Brinton (personal communication), Entomology Laboratory, Summerland, B.C., developed another excellent adhesive composed of 70 per cent sulphonated castor oil and 30 per cent glycerine. A mixture consisting of glycerine, water, and detergent has been used successfully

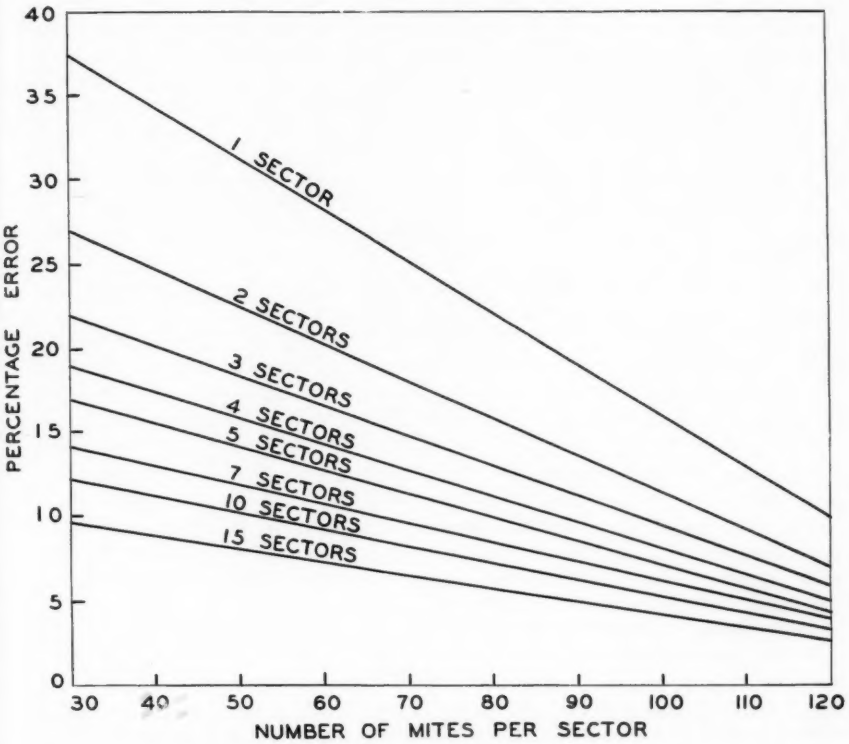

Fig. 6. Linear regression lines for percentage error in number of the European red mite per sector counted with the disk shown in Fig. 3.

by Mr. F. T. Lord (personal communication), Fruit Insect Section, Science Service Laboratory, Kentville, Nova Scotia.

Mites trapped on the adhesive-coated glass disk are counted with the aid of a paper counting disk permanently attached to another glass disk. The mounted counting disk is placed beneath the disk under examination and temporarily glued to it with rubber cement. The counting disk commonly used is made of extra thin photographic projection paper, and is divided into 16 sectors of equal area and 12 annuli of equal width (Fig. 2). Consequently each sector consists of 12 sections of unequal area. The area of each central section is $\frac{1}{2304}$ of the area of the disk, and the area of each peripheral section is $\frac{1}{100.17}$ of it. To facilitate counting, every odd-numbered sector is left white and the sections within the others are made alternately black and white. This arrangement permits one to make a 12.5, 25, 50, or 100 per cent count of the disk, depending on the number of mites and the uniformity of their distribution.

It was suspected, however, that the mites were not distributed evenly along the radius of the disk; therefore a new counting disk was constructed with sections of equal area (Fig. 3). It was drawn from the formula $r_n = \sqrt{n}\ r_1$,

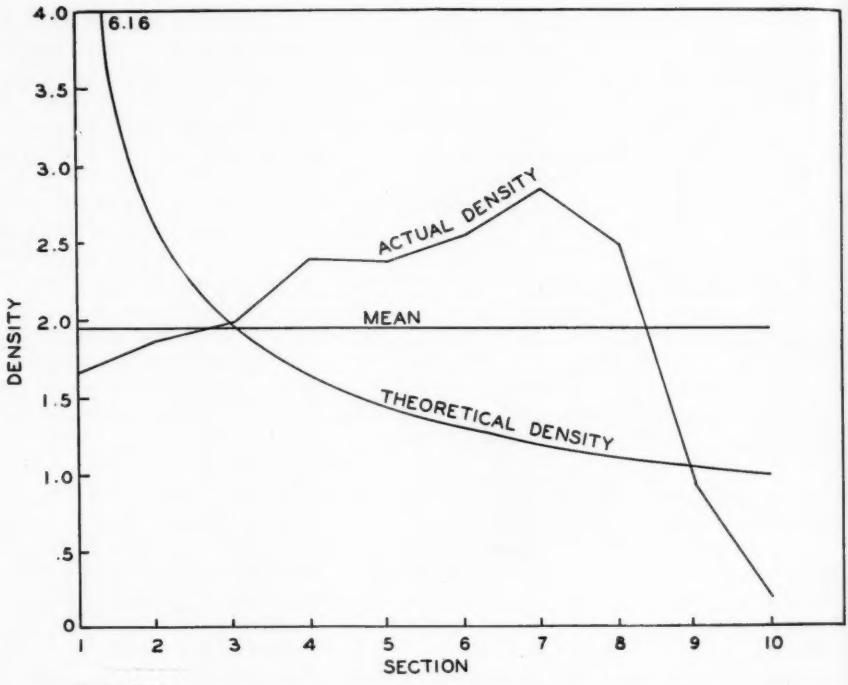

Fig. 7. Mean densities of the apple rust mite within sectors of six of the counting disks shown in Fig. 3. Section 1, apical section; 10, peripheral. Theoretical density of the n^{th} section, D_n=6.16 ($\sqrt{n}$-$\sqrt{n-1}$).

where r_n = the radius of the n^{th} concentric circle and r_1 = the radius of the first concentric circle; thus all annuli are of equal area. The new disk is divided into 10 equal annuli and 20 equal sectors, producing 200 sections of equal area. If the brushes distributed the mites evenly over the disk, their total number could be determined quickly by counting the number of mites in one or more sections. But, as indicated in Figs. 4 and 5, experiment showed that the distribution was not uniform. Two departures from a uniform distribution were noted: (1) More mites were deposited near the periphery of the disk than in the centre, as shown in Fig. 4. This was probably caused by the deflection of mites from the sides of the machine onto the edge of the disk. (2) There was a considerable variation in the density of mites from sector to sector around the disk. On one disk, for example, the number of mites per sector of the new counting disk ranged from 99 to 162, and averaged 126.

The percentage error between sectors decreases as the density of mites increases, as illustrated in Fig. 6. The number of sectors counted, therefore, can be adjusted according to the density of mites on the disk. If, for example, a 10 per cent counting error is tolerable, then 15 or more sectors should be counted at a population density of 30 mites per sector; if the density is about 80 mites per sector, then five or more sectors should be counted.

A suitable and accurate method has yet to be developed for counting eriophyid mites. The brushing machine is highly efficient in removing rust

mites from apple leaves, but the mites are so small and may be so numerous that counting is difficult. A thousand or more eriophyid mites per leaf is not uncommon, and, if the sampling unit consists of a number of leaves, the task of counting the population even on one sector is a lengthy and tiring one. It is feasible to count one or two sections per disk. The choice of these sections will be aided by Fig. 7, which illustrates the distributions of the apple rust mite, *Vasates schlechtendali* (Nal.), on six disks. Except for sections nine and ten, which lie outside the slides, sections five and six show the least variation. A correction factor should be applied to the count for either of these sections because its position in the distribution pattern lies above the mean of the sector. The distribution pattern of the apple rust mite differs noticeably from that of the European red mite. More eriophyid mites are deposited near the circumference of the disk and fewer at the centre than is the case with the European red mite. Since the distribution pattern may be affected by such factors as the mass of the mite, the size of the leaf, and the position of the mite on the leaf, presumably each species, and indeed each developmental stage, may show a distinctive distribution.

Although the brushing machine was originally designed for removing mites from foliage and fruit, it has also been used efficiently at the Summerland laboratory for removing summer eggs of the clover mite from the bark of apple twigs and spurs. The clover mite occurs both on the leaves and on the bark, and this peculiarity must be taken into account when sampling for it. Summers and Baker (1952) removed the mites from the leaves and bark of almonds by sharply tapping the twigs over a sheet of paper, on which the mites were crushed to produce a permanent record. But this procedure did not take account of the eggs. In the procedure developed at the Summerland laboratory, a twig bearing one or more fruit spurs, and not over 0.5 inches in diameter, is gently pruned from the tree. The leaves are removed and put through the brushing machine. Then the twig is cut into short lengths and these, in turn, are brushed. In this way a comparison may be obtained between numbers of mites and eggs, and between numbers on the foliage and on the bark. In a typical experiment the brushes removed from the bark all the active and quiescent stages and 93 per cent of the summer eggs of the clover mite. The method is not satisfactory for estimating numbers of winter eggs because these are attached too securely to the bark.

Acknowledgments

The authors wish to thank Mr. D. B. Waddell, Stored Product Insect Unit, Entomology Division, Ottawa, formerly of the Entomology Laboratory, Summerland, B.C., for photographing of equipment, and Mr. H. R. Boyce, Entomology Laboratory, Harrow, Ont., for permitting the use of unpublished information.

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(Received February 9, 1955)

Cheesecloth Flight Traps for Insects

By HUGH B. LEECH[1]

The appearance of an article "Window flight traps for insects" by Chapman and Kinghorn (*Can. Ent.* 87 (1): 46-47. 1955) suggests that it may be well to describe another flight trap. Specimens taken by it have been labelled "caught in cheesecloth trap", a statement which is true but perhaps enigmatic.

While on the late Ralph Hopping's staff, the writer built a number of cages for rearing forest insects in southern British Columbia. These cages were all 6 x 6 x 6 ft., each on a cloth covered wooden platform, with a minimum superstructure of 2 x 2 in. lumber to the inside of which cheesecloth was tacked to form an insect-tight enclosure. One entered by a door on the lower part of the north or east side.

In applying the cloth the ceiling was usually put on first, then the wall facing the doorway, and the two adjoining sides. On sunny days these partially completed cages caught a surprising number of flying insects, which seemed to be attracted to the white cloth, just as they are to white tents.[2] The essential feature was that the cages be in the sunlight in a wooded area, with the open side away from the sun, preferably to the north.

Remembering this, the writer built a "cheesecloth trap" of this sort at the south end of a north-south pathway through a redwood grove in Mill Valley, Calif. Perfect specimens of many species not otherwise found in years of collecting in the same area, have been taken. Diptera and parasitic Hymenoptera enter the trap in greatest numbers, with Coleoptera and Hemiptera also common. For best results the trap should be visited regularly during the day, but as long as the sun is shining through it a majority of the insects will stay inside. A 6 x 6 ft. south end, short east and west walls, and a top with a fringe hanging down a foot or so, are enough. The insects fly in from the north, stay on the south wall where the light is strongest, and in most cases are prevented from leaving because of the short sides and fringed top. It is probable that a $\wedge$-shaped trap would be simpler to make, and would lose fewer specimens. A floor is somewhat of a luxury, but does retain those insects, especially small beetles, which tend to hide rather than take to flight again after falling down.

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2It is possible that some other colours would be even more effective. See "A method for taking aphids in flight", by F. C. Hottes, *Pac-Pacfiic Ent.* 27 (4): 190. 1951.

(Received May 5, 1955)

The External Morphology of the Five Forms of *Pineus pinifoliae* (Fitch) (Homoptera: Phylloxeridae)[1]

By G. R. UNDERWOOD[2]

Introduction

Pineus pinifoliae (Fitch) was first described (6) in 1858 under the name *Chermes pinifoliae*. His description of the adult gallicola migrans on the needles of white pine contained characteristic phases of the form sufficient to distinguish it from other Adelginae. Thomas (13), in 1879, described the characteristic cone-like gall on spruce and named the species forming the gall *Chermes abieticolens*. In 1906 Patch (12) observed the migration of the gallicola migrans from galls on black spruce, *Picea mariana* (Mill.) B. S.P., to the needles of white pine, *Pinus strobus* L., thus proving that *Chermes abieticolens* Thomas was a synonym of *Chermes pinifoliae* Fitch. She described the nymph and adult of the gallicola migrans and sexupara and included a drawing of the adult gallicola migrans. In 1928 Annand (1) revised the Adelginae and placed the species in the genus *Pineus*. He described and figured the fundatrix, gallicola migrans, and exsulis.

The species has been recorded in eastern North America throughout most of the range of the eastern white pine. It has been taken in Newfoundland and the Maritime Provinces (4) and has been recorded in the literature from Maine (2, 12), Connecticut (5), Vermont (3), New Hampshire (11), New York (6), North Carolina and Tennessee (7, 8), and Michigan (10). Samples of white pine, heavily infested with this species, were received from Mr. C. E. Ahlgren of the Quetico Superior Wilderness Research Center, Ely, Minnesota, in 1954. It has also been found throughout most of the range of the western white pine, *Pinus monticola* Dougl. in western North America (1). The species has not been recorded outside of North America and is evidently indigenous to this continent. It probably occurs throughout the range of its hosts and the limited number of records may be attributed to its small size and the difficulty of identification.

In 1941 the insect was found to be epidemic in New Brunswick, and Balch and Underwood (4) have since described the life cycle and effects of the insect on white pine. It has five forms which alternate between red or black spruce and white pine in New Brunswick. During the course of this study it was necessary to undertake studies of the external morphology in order to identify the species and its various forms. Identification of the Adelginae is often difficult owing to the complex life cycles and the number of morphologically distinct forms. Any study of the relationship of the forms requires rearing of pure cultures on the primary and secondary hosts. This paper redescribes the forms of the fundatrix, gallicola migrans, and exsulis, and describes the sexupara and sexualis, which have not been previously recognized.

Terminology

The five forms or distinct generations in the life cycle are named according to Marchal (9).

Fundatrix.—Apterous parthenogenetic female that hatches from the egg laid by the female sexualis on red spruce, and overwinters as a first-stage larva, completing its development in the spring. It lays a large number of eggs and contributes to the formation of the gall on red spruce.

[1]Contribution No. 205, Forest Biology Division, Science Service, Department of Agriculture, Ottawa, Canada. (Some of the work was done as part of a thesis submitted in partial fulfilment of the requirements for the degree of M.A. at the University of Toronto.)

[2]Agricultural Research Officer, Forest Biology Laboratory, Fredericton, New Brunswick.

Gallicola migrans.—Winged parthenogenetic female, progeny of the fundatrix on the primary host. The larva settles at the base of a needle on a new shoot. This form completes the formation of the gall. After the fourth molt the winged adult leaves the gall and flies to a white pine needle and oviposits.

Exsulis.—Apterous parthenogenetic female that develops from the egg of the gallicola migrans and gives rise to other generations of exsules on white pine shoots.

Sexupara.—Winged parthenogenetic female, progeny of the gallicola migrans. Overwinters as first-stage larva on a white pine shoot. In the spring after development to adult, flies to the red spruce and settles on a needle and oviposits.

Sexualis.—Small apterous male or female, progeny of the sexupara on the primary host.

The immature stages are referred to as "larvae" with the exception of the pre-adult stage of the winged forms, for which the term "nymph" is used. The first-stage larvae during the motile period, from hatching to time of insertion of the stylets, are termed "crawlers". All other stages of all the forms are sedentary with the exception of the adult alates and sexuales.

The sclerotized plates with pores and setae on the dorsum of all stages and forms are arranged in longitudinal rows. Starting next to the midnotal line the first row is called the mesial; the second row, the pleural; the third row, the marginal. Where fusion of plates has occurred, particularly on the head and thorax in the adult stages, the longitudinal arrangement may be difficult to define.

Description

The following descriptions are based on microscopic examination of living and mounted material. First-stage larvae were mounted directly in Buxton's mounting medium or were cleared in carbo-xylol for a few hours and mounted in Canada balsam. The other stages were mounted in balsam after the following treatment. The abdomen and wings were punctured with a fine needle to facilitate clearing. They were then placed in a 6 per cent solution of potassium hydroxide and heated over boiling water until cleared, usually two to four minutes. They were immediately removed to distilled water and the body contents teased through the punctures by the pressure of a small pin on the thorax. They were washed in a second bath of distilled water and dehydrated in 30, 70, and 95 per cent ethyl alcohol, for one hour. When staining was required, basic fuchsin was added to the alcohol in each step of the dehydration process. Excess stain was removed in clear 95 per cent alcohol. The specimens were then placed in carbo-xylol for 15 minutes and mounted in Canada balsam.

The outlines of the insect and its appendages were drawn with the aid of a microscope projector and camera lucida. Descriptions and drawings are confined to the first instar and adult of the apterous forms and the first instar, nymph, and adult of the alate forms. It was considered unnecessary to describe intermediate instars. In general they resemble the adults or nymphs, showing somewhat fewer pores and sclerotized plates.

During molting new stylets are formed and inserted close to the old stylets, which attach the exuviae to the bark. Thus the cast skins are found in a complete series beside the adult and permit the easy identification of instars. The two alate forms, gallicola migrans and sexupara, and the sexualis each have five instars. The fundatrix and exsulis each have four instars.

The size and number of wax pores and sclerotized plates on the dorsum are not constant between individuals or within individuals between the left and right side. Counts were made of pores on the dorsum of five adult exsules. The results are shown in the following synopsis:

	Head		Prothorax		Mesothorax		Metathorax	
	Left	Right	Left	Right	Left	Right	Left	Right
Minimum.....	46	39	79	83	65	55	51	43
Maximum.....	72	80	119	128	96	77	78	79
Average.....	61	62	96	98	83	69	67	66

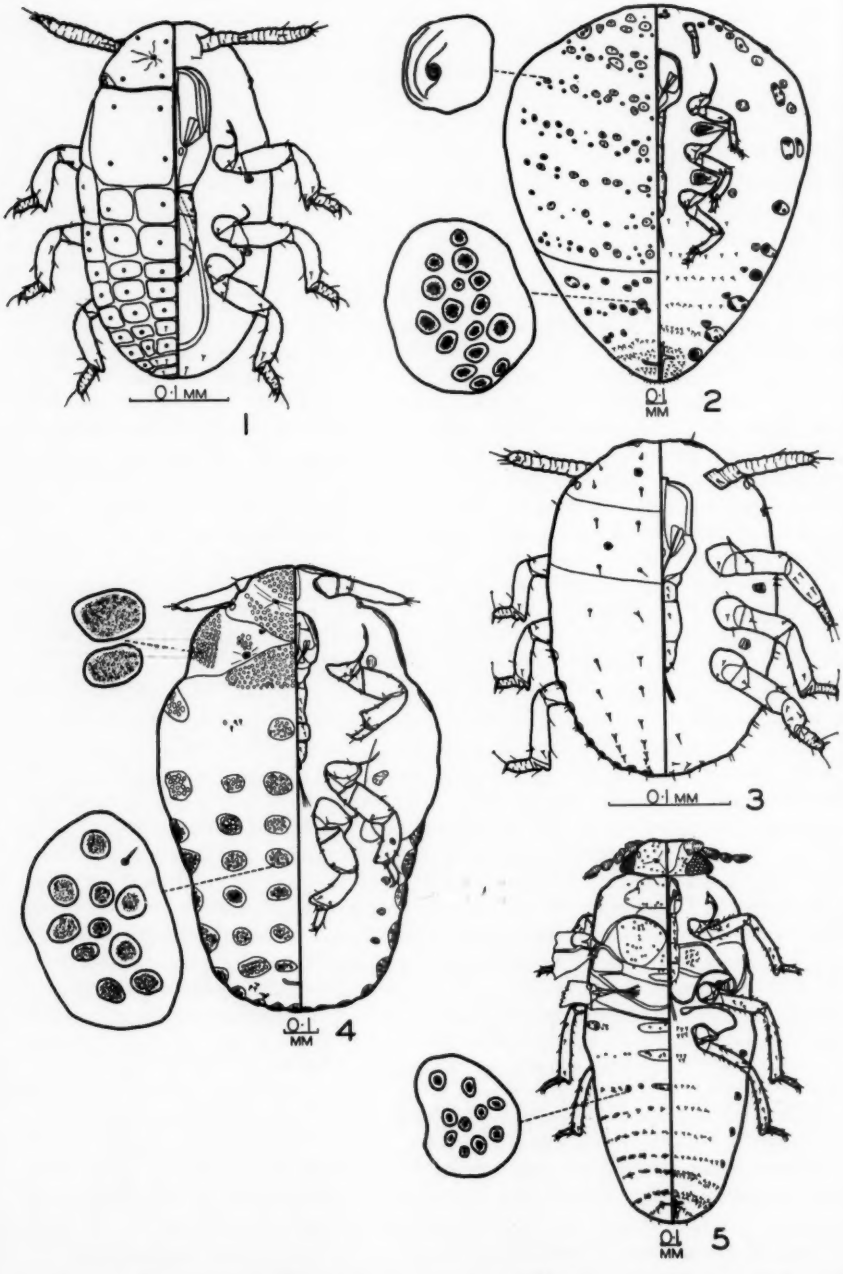
Fundatrix

First Instar (Fig. 1).—Body about 0.35 mm. by 0.20 mm., oval in outline, flattened ventrally, moderately convex dorsally. Light reddish-brown following hatching, head and thorax gradually becoming black and abdomen dark reddish-brown a few days after insertion of stylets. Two large plates on head, each with four pores. Prothoracic and mesothoracic plates fused on each side of mid-notal line, each with four pores. Plates on the metathorax and first six abdominal segments arranged in six rows, each plate containing one pore and the marginal plates occasionally two; these may be replaced by setae on caudal area of abdomen. Plates fused in each of remaining abdominal segments. Pores simple and small on a slightly raised, cone-shaped projection. Antenna 3-segmented; slightly longer than rostrum; third segment twice as long as first and second combined, with sensoria near distal end. The 3-jointed rostrum, between the coxae, extends caudally to the metathoracic coxae. Each tarsus with a pair of knobbed setae. Three ocelli grouped on a plate on each side of head. A pair of spiracles borne on each of the mesothoracic and metathoracic segments only.

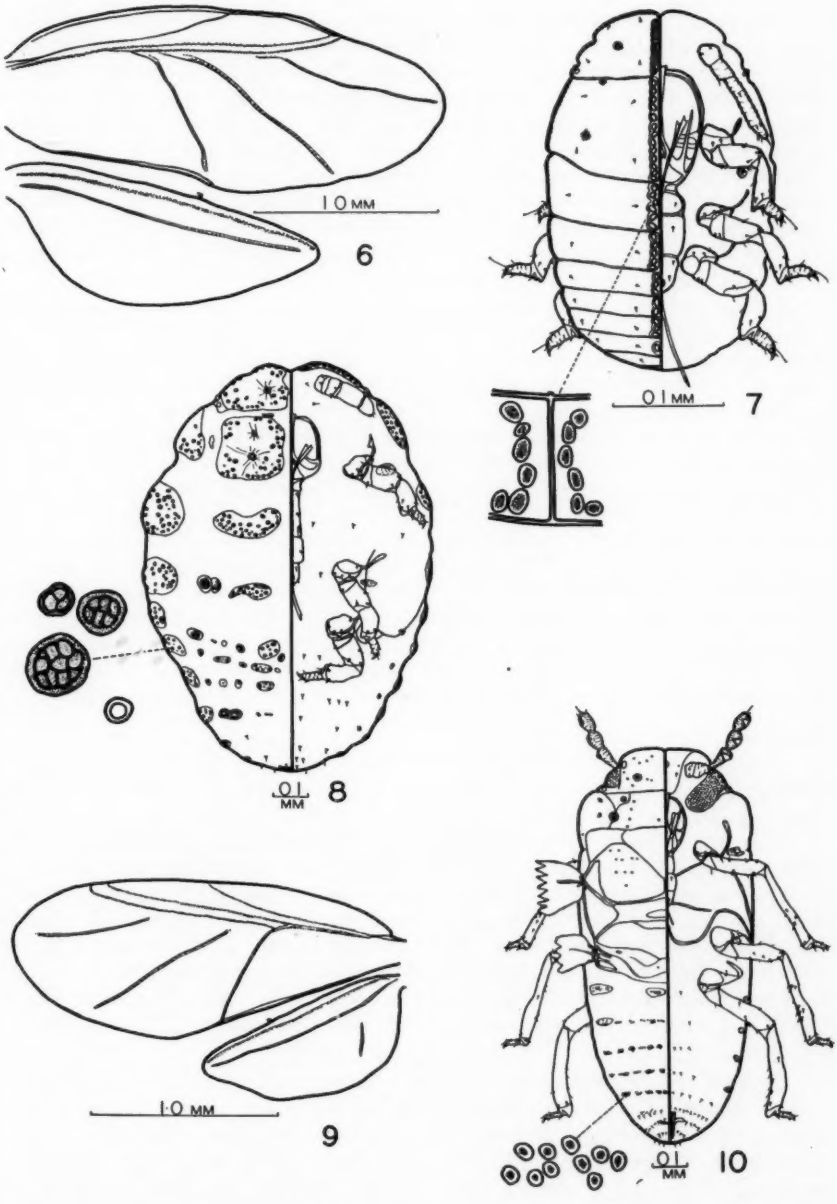
Adult (Fig. 2).—Body about 2.0 mm. by 1.7 mm., black. Thorax broad and strongly arched on dorsum. Head, thorax, and first three abdominal segments covered with a sclerotized shield, with each simple, raised pore defined by a heavily sclerotized area. Small flat plates each bearing a number of pores on the fourth to seventh abdominal segments. Marginal row of plates placed ventrally; first marginal plate of prothorax with half of plate set with large angularly divided pores; simple pores on part or all of remaining marginal plates. Coxal plates of the second and third pair of legs with simple pores. Setae on the last three abdominal segments. Antenna one-third length of rostrum; third segment over twice as long as second; sensoria at distal end of third segment. The 3-jointed rostrum extends slightly beyond the metathoracic coxae. Three ocelli grouped on a plate on each side of head. Spiracles are borne in pairs on the mesothoracic and metathoracic segments and on the second to fifth abdominal segments inclusive.

Gallicola Migrans

First Instar (Fig. 3).—Body about 0.3 mm. by 0.2 mm., broadly oval, moderately convex dorsally, light reddish-brown. Two sclerotized plates on head, each with four setae; prothoracic and mesothoracic plates fused, lightly sclerotized, with two setae in each mesial and pleural row. Integument of metathorax and abdomen not sclerotized, but with mesial and pleural rows of setae. Marginal row of plates bearing simple pores and setae along entire length. Antenna 3-segmented; slightly longer than rostrum; third segment over twice as long as first and second combined; sensoria near distal end of third segment. Legs twice as long as rostrum; each tarsus with a pair of knobbed setae. Three ocelli



Figs. 1-5. *Pineus pinifoliae* (Fitch). 1, Fundatrix, first instar; 2, Fundatrix, adult; 3, Gallicola migrans, first instar; 4, Gallicola migrans, nymph; 5, Gallicola migrans, adult.



Figs. 6-10. *Pineus pinifoliae* (Fitch). 6, Gallicola migrans, wing; 7, Sexupara, first instar; 8, Sexupara, nymph; 9, Sexupara, wing; 10, Sexupara, adult.

grouped on each side of head. One pair of spiracles on each of the mesothoracic and metathoracic segments only.

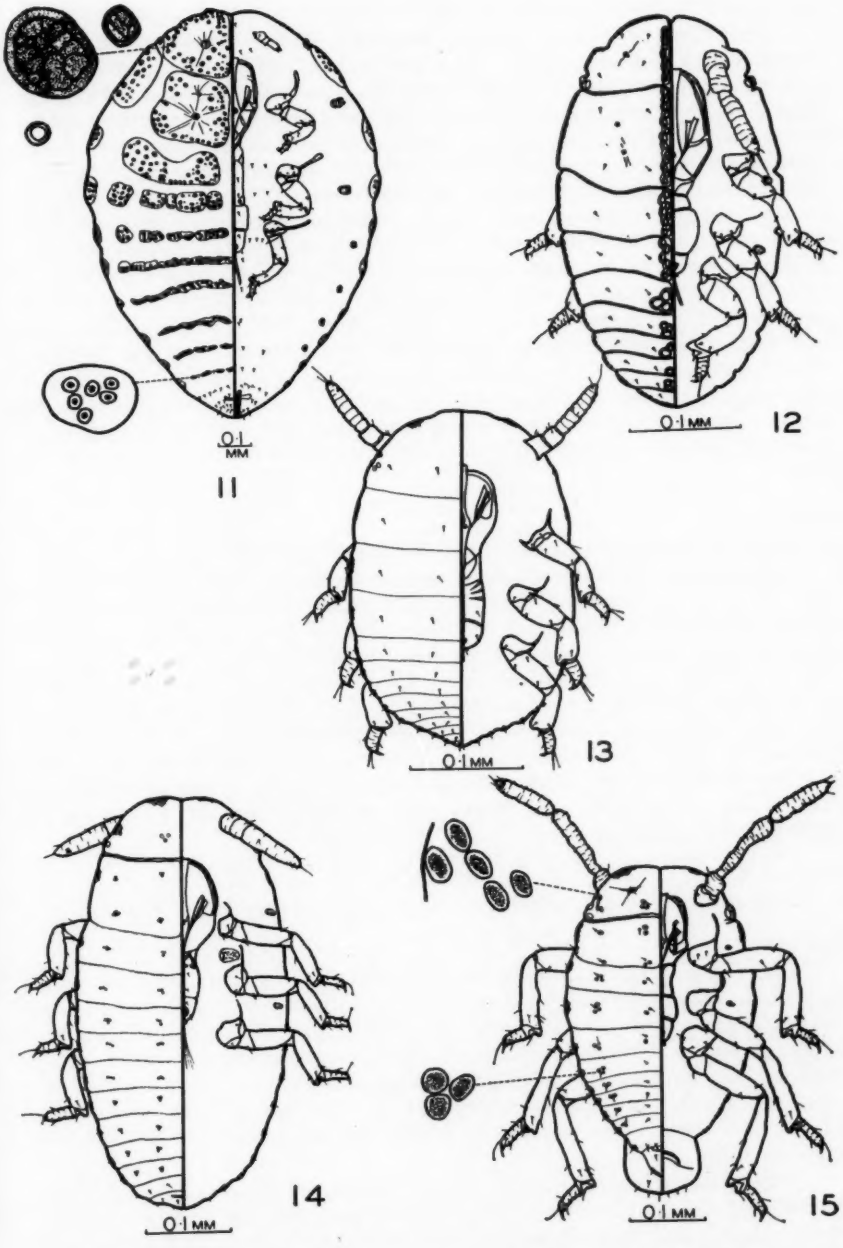
Nymph (Fig. 4).—Body about 1.4 mm. by 0.8 mm. Head and thorax dark brown, abdomen reddish-brown. Sclerotized areas of head and prothorax with large groups of large pores, sub-rectangular to oval in outline; mesothoracic, metathoracic and first five abdominal segments with large rounded sclerotized plates, each with many large pores; marginal row of plates from mesothorax to ninth abdominal segment inclusive. Antenna 3-segmented; slightly longer than rostrum; third segment longer than first and second combined; sensoria near distal end of third segment. A group of three ocelli on each side of head. One pair of spiracles on each of the mesothoracic and metathoracic segments and the second to fifth abdominal segments inclusive. The external, heavily sclerotized wing pads closely appressed to sides of body.

Adult (Fig. 5).—Body about 2.2 mm. by 1.0 mm. Head and thorax black, abdomen reddish-brown. Head and thorax heavily sclerotized with pores small and scattered. A few sclerotized plates with small pores on the first three abdominal segments; pores in transverse rows on fourth to eighth abdominal segments inclusive; ninth segment with setae. Antenna 5-segmented, about same length as rostrum, last three segments bearing large sensoria, a group of small circular sensoria near distal end of last segment. Legs over twice as long as rostrum; setae abundant on tibia and femur. Compound eye large; an ocellus on the vertex of the head, one near the dorsal margin of each compound eye, three on a marginal plate posterior to each compound eye. Two pairs of large spiracles borne on the mesothoracic and metathoracic segments, smaller spiracles on the second to fifth abdominal segments inclusive. Wings fold in a roof-like position over abdomen at rest; forewing with radial sector faintly marked; media, cubitus, and anal veins distinct and joined to radial sector (Fig. 6). The hindwing with only one vein, radial sector. The wing coupling made up of seven or eight fine hamuli which engage a fold in the forewing near end of anal vein.

SEXUPARA

First Instar (Fig. 7).—Body about 0.3 mm. by 0.2 mm., broadly oval, flattened ventrally, moderately convex dorsally, dark reddish-brown in colour. All segments sclerotized with interstices between segments narrow; prothoracic and mesothoracic segments fused; eighth and ninth abdominal segments not discernible, apparently fused with seventh segment. Mesial row of pores and setae from head to fifth abdominal segment inclusive; pleural row of setae; marginal row of pores from head to last abdominal segment inclusive. Antenna 3-segmented; slightly longer than rostrum; third segment over twice as long as the first and second combined; sensoria near distal end of third segment. Legs longer than rostrum; each tarsus with a pair of knobbed setae. Three ocelli grouped on each side of head. One pair of spiracles on each of the metathoracic and mesothoracic segments only.

Nymph (Fig. 8).—Body about 1.2 mm. by 0.8 mm., broadly oval, moderately convex on dorsum. Head and thorax dark reddish-brown, abdomen light brown. Sclerotized plates on head, thorax, and abdomen separated by wide areas of non-sclerotized integument; marginal row of plates extended to seventh abdominal segment. Pores large, divided into angular sections, generally concentrated around edge of plates. Antenna 3-segmented; two-thirds as long as rostrum; third segment twice as long as first and second combined. Legs as long as rostrum. Three ocelli grouped on a plate on each side of head. One pair of spiracles on each of the mesothoracic and metathoracic segments and the second



Figs. 11-15. *Pineus pinifoliae* (Fitch). 11, Exulis I, adult; 12, Exulis II, first instar; 13, Sexualis, first instar; 14, Sexualis, female adult; 15, Sexualis, male adult.

to fifth abdominal segments inclusive. The external, heavily sclerotized, wing pads closely appressed to sides of body.

Adult (Fig. 10).—Body about 1.3 mm. by 0.5 mm. Head and thorax black, abdomen dark reddish-brown. Head and thorax heavily sclerotized with few pores; sclerotized plates with small, simple pores on first two abdominal segments; pores in transverse rows on first five abdominal segments; remaining segments with setae. Antenna 5-segmented, about as twice as long as rostrum; the last three segments bearing large sensoria; a group of small sensoria near distal end of fifth segment. Legs over twice as long as rostrum; setae abundant on tibia and femur. A large compound eye of many facets on each side of head; an ocellus on the vertex, one near the margin of each compound eye, and three ocelli borne on a plate posterior to each compound eye. One pair of large spiracles borne on each of the mesothoracic and metathoracic segments; small spiracles on the second to fifth abdominal segment inclusive. Wings folded in a roof-like position over dorsum at rest; forewings with radial sector faintly outlined, media and cubitus do not appear to be joined to radial sector as is the anal vein. (Fig. 9). Hindwings with radial sector running full length of wing; media present, but not joined to radial sector. Wing coupling made up of three or four hamuli on the hindwing that makes contact with a fold in the middle hind margin of the forewing.

EXSULIS I

First Instar.—Similar to first-instar sexupara larva (Fig. 6).

Adult (Fig. 11).—Body about 1.2 mm. by 0.8 mm., oval in outline. Head and thorax black, abdomen dark reddish-brown. Sclerotized plates on head, thorax, and abdomen separated by wide areas of non-sclerotized integument; plates on first to sixth abdominal segments inclusive. Pores large, divided into angular sections, generally concentrated around edge of plates with small, simple pores widely scattered on head and thorax, increasing in number on the abdomen. Last three abdominal segments with setae. Antenna 3-segmented, about one-quarter the length of rostrum. Legs about two-thirds the length of rostrum. A group of three ocelli on plate on each side of head. A pair of spiracles on each of the mesothoracic and metathoracic segments and the second to fifth abdominal segments inclusive.

EXSULIS II

First Instar (Fig. 12).—Similar to first-instar sexupara larva (Fig. 6).

SEXUALIS

First Instar (Fig. 13).—Body about 0.3 mm. by 0.2 mm., oval in outline, moderately convex dorsally, light reddish-brown in colour. Head, thorax, and abdomen lightly sclerotized. Mesial and pleural rows of seta; marginal row of pores and setae. Antenna 3-segmented, about as long as rostrum; third segment twice as long as first and second combined; sensoria near distal end of third segment. Tarsus with a pair of knobbed setae. A group of three ocelli on each side of head. One pair of spiracles on each of the metathoracic and mesothoracic segments only.

Adult Female (Fig. 14).—Body about 0.4 mm. by 0.2 mm., oval in outline, dark reddish-brown in colour. Head, thorax, and abdomen lightly sclerotized. Mesial, pleural, and marginal rows of small simple pores from head to the eighth abdominal segment; plates with small pores on sub-coxae of middle pair of legs. Antenna 3-segmented, longer than rostrum, third segment over twice as long as first and second combined; a group of sensoria near distal end of each antenna.

Legs over twice as long as rostrum; each tarsus with a pair of knobbed setae. A group of three ocelli on each side of head. A pair of spiracles on each of the mesothoracic and metathoracic segments only.

Adult Male (Fig. 15).—Body about 0.4 mm. by 0.2 mm., oval in outline with posterior abdominal segment projected and truncate, reddish-brown in colour. Head, thorax, and abdomen lightly sclerotized. Mesial, pleural, and marginal rows of small, simple pores and setae. Antenna 4-segmented, over twice as long as rostrum; combined length of third and fourth segment nearly five times as long as first and second combined; sensoria near distal end of fourth segment. Legs over twice as long as rostrum; tarsus with a pair of knobbed setae. A group of three ocelli on plate on each side of head. A pair of spiracles on each of the mesothoracic and metathoracic segments only.

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Biology of the Red Clover Thrips, *Haplothrips niger* (Osborn) (Thysanoptera: Phloeothripidae)[1]

By Conrad Loan[2] and F. G. Holdaway[3]

The red clover thrips, *Haplothrips niger* (Osb.), was first recorded from the state of Iowa and described by Osborn in 1883 under the name *Phloeothrips nigra*. The species has since been collected and observed in many parts of the United States, southern Canada, and Europe. It was reported in New England and recognized as a potential pest of red clover by Muggeridge (1933). Minute and very active, the adult insect is glossy black in contrast to the nymphal stages, which are bright red. In Minnesota, common host plants are alsike clover, *Trifolium hybridum* L., and red clover, *T. pratense* L.

During early and mid summer the host flowers may harbour great numbers of the immature and adult thrips. This has caused concern to the producers of alsike and red clover seed. From 50 to 80 adult thrips may occur in a single flower head. When such numbers are present the corollas are marked with rusty-brown patches and some of the florets appear shrivelled (Figs. 19-21). Yates (1952) has given an account of the extent and type of injury caused by the thrips in New Zealand.

This is a report on an investigation of the life-history and habits of the red clover thrips. The work was carried out at University Farm, University of Minnesota, St. Paul, Minnesota, U.S.A., during the summer of 1952. Additional observations were made at Belleville, Ontario, Canada, during the summer of 1953. The chaetotaxy of the immature stages, important for identification, had not been adequately described; the adult, however, was described by several authors (Osborn, 1883; Hinds, 1902; Priesner, 1928; Morison, 1949), and the synonymy was fully dealt with by Priesner. The synonyms *H. statices* (Hal.) and *H. leucanthemi* (Schr.) frequently appear in North American literature. The common names *black clover thrips* and *statices thrips* should be referred to *H. niger*.

Methods

The species was studied in the laboratory, in the insectary, and in the field. Early in June, 1952, adults were collected from the field as parental stock for rearing. A small number of females were caged in each of several small shell vials (15 x 60 mm.) with a few tripped alfalfa florets. Oviposition occurred readily within the corolla of the floret. The eggs were collected and placed individually in one-dram vials stoppered with absorbent cotton. The vials were held in a closed glass container at 25°C. on a stage over a small volume of water. The thrips developed from egg to adult in these chambers and in this way the immature stages and adults were obtained for study. The nymphs and adults were fed individual florets of white clover, *Trifolium repens* L. Laboratory-reared females were used for studies on fecundity and oviposition.

The laboratory work was duplicated, on a smaller scale, in the insectary. Data on reproduction under variable insectary conditions were obtained from females reared previously at 25°C. and transferred to the insectary after emergence.

1Contribution No. 3276, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada, and Paper No. 3172, Scientific Journal Series, University of Minnesota Agricultural Experiment Station, St. Paul 1, Minn., U.S.A.; from a thesis submitted by C. Loan to the Faculty of the Graduate School of the University of Minnesota in partial fulfilment of the requirements for the degree of Master of Science, 1953.

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To obtain information on seasonal development, thrips were caged in the field with heads of volunteer red clover in dialyzing tubing. Mature clover heads and surface debris on the ground below the plants were examined for thrips with a low-power binocular or treated in a Berlese funnel.

Descriptions of the Life Stages

The life stages consist of the egg, two nymphal instars, a prepupal instar, two pupal instars, and the adult.

Egg

The egg (Fig. 14) is subcylindrical, rounded posteriorly, and gradually tapering toward its anterior end, which is constricted into a round, knoblike process. The chorion appears smooth under low magnification, but at high magnification (490X) the surface is seen to be sculptured with a pattern of hexagonal cells of irregular sizes. The dimensions of 25 eggs were: length, 433-500 μ; width, 137-150 μ.

Nymph

The newly-hatched nymph (Fig. 1) is transparent amber in colour and microscopic in size. The pterothorax and abdomen have an unexen appearance caused by small, raised sclerotized areas that bear bristles. The chaetotaxy of the nymph is shown in Figs. 2-5. After feeding, the nymph takes on a pink colour, which changes to bright red on completion of intra-stadial growth. The mature instar may reach 1100 μ in length, almost double its length at eclosion.

The second-instar nymph (Fig. 9) is mainly shining red; the appendages, the sclerites of the pronotum, abdominal segment X, and the posterior half of segment IX are dark brown to black. The chaetotaxy of this instar is shown in Figs. 6-8 and 10. The pterothorax and abdomen have a swollen or globose appearance. The length of the mature instar is approximately the same as that of the adult.

Prepupa and Pupa

The prepupa (Fig. 11) is distinguished by short, porrect antennal sheaths, the glassy-clear colour of the appendages and of the terminal abdominal segment, and the absence of wing sheaths. The body colour is pale red.

The first-instar pupa (Fig. 12) is distinguished by the shape and position of the antennal sheaths, which lie alongside and parallel with the lateral margins of the head capsule. Wing sheaths are present and extend to abdominal segment II.

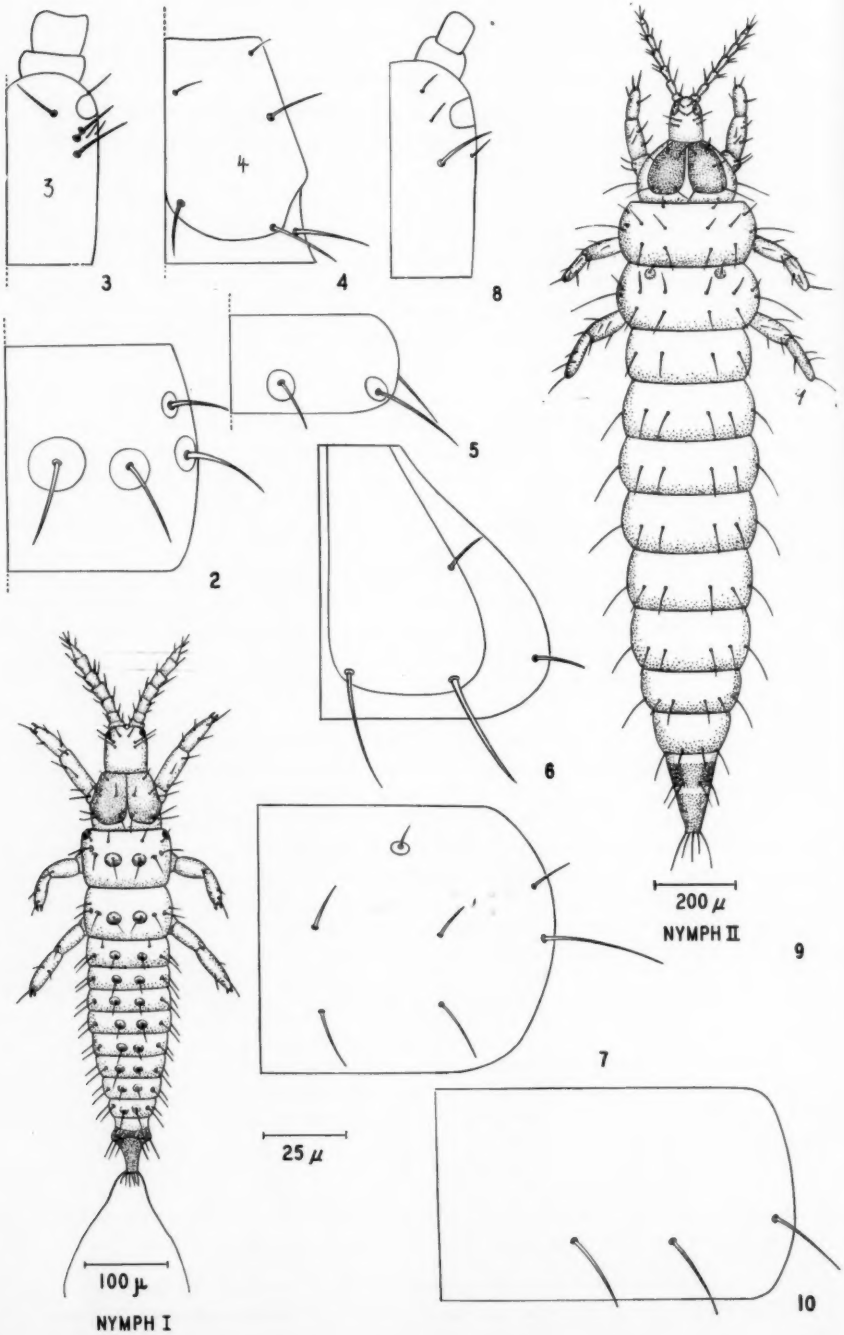
The second-instar pupa (Fig. 13) is somewhat similar in form to the adult. The antennal sheaths, with their tips curved ventrally, lie adjacent to the head, and touch or closely approximate the mouth-cone. The wing sheaths are broad at the mesothorax and extend to abdominal segment IV. The abdomen has a flattened appearance, its apex terminating in a narrow sheath.

Adult

The newly emerged adult is pale red. Its appendages are glassy-clear. Frequently the head is transparent, with a dorsal red blotch. Within 10 hours at 25°C., the adult acquires the glossy-black appearance of the mature insect and can no longer be recognized as a recent emergent (Fig. 17). An occasional adult in the field may be dark red. The mean length of the adult is about 1900 μ (range, 1415-2268). The abdomen is somewhat flattened and tapered toward its apex. Its tip is tubelike and fringed with setae. Strong bristles are absent from the head, thorax, and abdomen. The wings bear 7-9 accessory cilia.

Development and Behaviour of the Immature Stages

The mean period for egg development in the laboratory at 25°C. was 4.6 days (4.0-6.0). For eggs reared in the insectary at Belleville in early June, 1953,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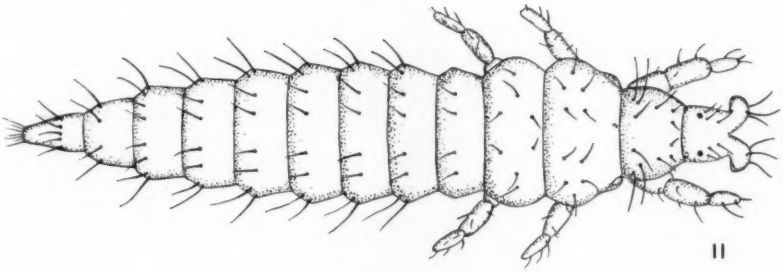
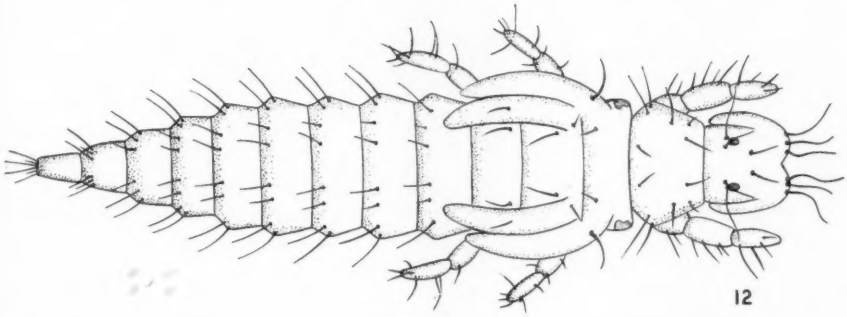
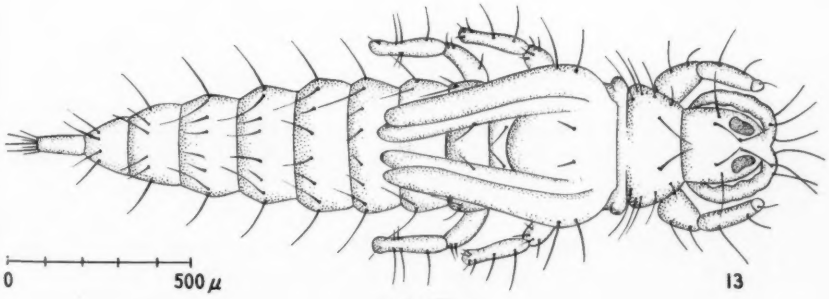


PREPUPA



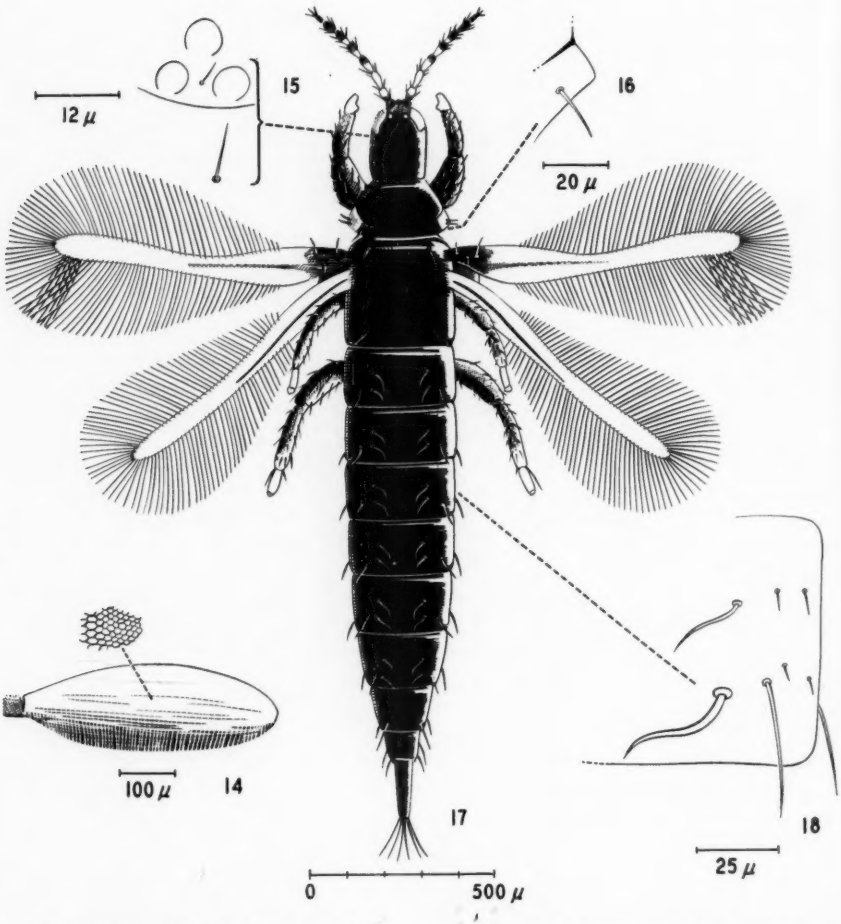
PUPA I



PUPA II

Figs. 1-10. *Haplothrips niger* (Osb.). Nymphal instars and chaetotaxy. 1, Dorsal view of Nymph I; 2, Mesothorax of Nymph I; 3, Head of Nymph I; 4, Prothorax of Nymph I; 5, Abdominal segment II of Nymph I; 6, Prothorax of Nymph II; 7, Mesothorax of Nymph II; 8, Head of Nymph II; 9, Dorsal view of Nymph II; 10, Abdominal segment II of Nymph II.

Figs. 11-13. *Haplothrips niger* (Osb.). Pupal instars. 11, Dorsal view of prepupa; 12, Dorsal view of Pupa I; 13, Dorsal view of Pupal II.



Figs. 14-18. *Haplothrips niger* (Osb.). Adult, egg, and chaetotaxy of the adult. 14, Egg; 15, Post-ocular bristle; 16, Postero-angular bristle of the prothorax; 17, Dorsal view of adult female; 18, Chaetotaxy of abdominal segment IV.

the range was 10.0-12.0 days. The newly laid egg is pale fleshy-white; within 36 hours at 25°C. after the hardening of the chorion, the colour changes to a glistening white. From this time on the appearance of the egg changes with the development of the embryo. In 48 hours the small, red eyes of the embryo are visible, and the posterior portion of the egg changes to a pale amber. The antennae become prominent within 84 to 96 hours. They are dark grey in colour and slightly less than one-third as long as the egg. At this stage of development the embryo, which is now pale orange in colour, is about ready to hatch.

In the laboratory at 25°C. the first nymphal stadium is completed in a mean period of 6.0 days (5.0-9.0). In the insectary the mean was 8.8 days (6.0-12.0). The nymph usually emerges from the anterior, knobbed end of the egg. The chorion is ruptured and the nymph wriggles free. Nymph I at first remains

beside the egg-shell but soon it slowly examines the immediate surroundings, with a continual flexing of the antennae. When placed on a floret it quickly searches the new surroundings and begin to feed on pollen grains. More often it quickly disappears from view in the floret, where it may move about, feeding on the protoplasm of plant cells or pollen grains. The first-instar nymph sheds its cuticle within the floret or in some sheltered spot on the inflorescence.

The duration of the second nymphal instar is frequently prolonged by the occurrence of diapause. Of 50 nymphs reaching the second instar at 25°C., only three pupated within 99 days. These completed nymphal development in six, seven, and nine days. Insectary rearing at Belleville in June, 1953, produced similar results. Field collections of fully developed second-instar nymphs were made at Belleville on June 30, July 4, and July 6, 1953. A total of 54 nymphs pupated in 1953 from approximately 200 nymphs collected on these dates. As with the first-instar nymph, the activities of Nymph II are chiefly concerned with feeding. Nymph II was observed moving about the anthers, collecting pollen with the fore tarsi and feeding on the contents of pollen grains. Individuals were observed bearing large clumps of pollen on the appendages and body. The nymph also feeds on the protoplasm of cells of the floral parts. Both nymphal instars may be cannibalistic and will feed on one another if food is withheld from them. Although this species is communal in habit, the individuals keep clear of one another.

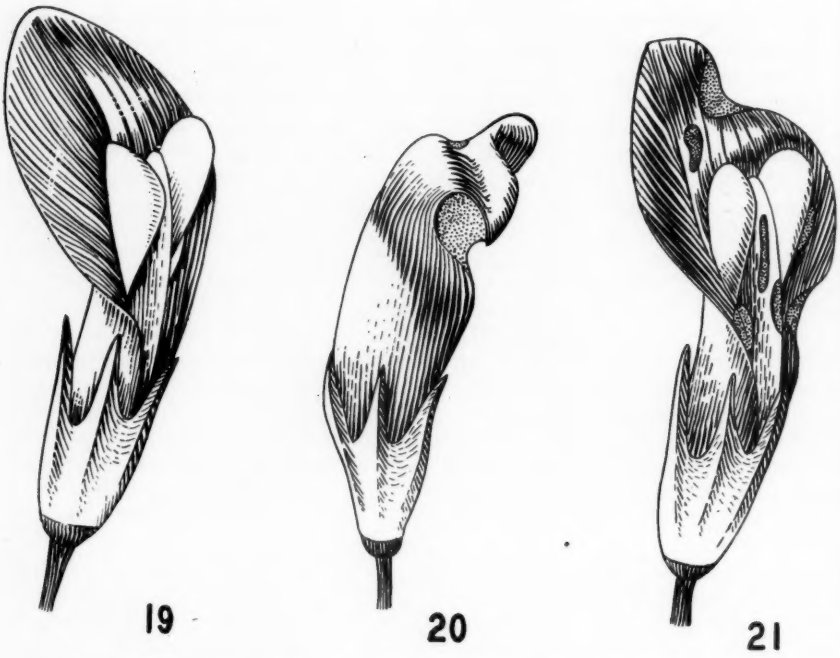
At 25°C. the prepupal instar is completed in a mean period of 1.5 days (1.0-2.0); Pupa I, 1.4 days (0.4-2.0); Pupa II, 3.7 days (1.5-4.8).In late June, 1953, in the insectary at Belleville, the mean duration of the prepual instar was 3.2 days (2.0-5.0); of Pupa I, 2.2 days (2.0-3.0); of Pupa II, 5.2 days (3.0-7.0). The prepupa, Pupa I, and Pupa II are resting stages. Though normally quiescent for the three moults, they change position if disturbed, particularly Pupa II. In these three instars the insect is negatively phototactic, in contrast to the nymphal and the adult stages, in which it is attracted to light. As development proceeds, the adult form within the cuticle of Pupa II is clearly evident, and the segments of the antennae, the compound eyes, and the cilia of the wings can be recognized.

Reproduction

The species is oviparous, and reproduction is parthenogenetic. Virgin females laid fertile eggs in all cases. No males were found in the field or appeared in laboratory rearing. Dr. H. Priesner (personal communication), Fouad I University, Cairo, stated that he had not found a single male that "could with *absolute certainty* be attributed to this species". Yates (1952) described what she considered to be the male as "smaller than the female, with forelegs thickened and fore-tarsi bearing a well-developed tooth". Since many females are small and have the other characters mentioned, these features by themselves cannot be taken as evidence of males within the species.

The female oviposits both within the well-developed florets and between the small, undeveloped florets of white clover. It may also place the eggs between the points of the calyx and the base of the corolla. On alfalfa, the eggs are often laid on the lower centre of the standard petal or between the keel and wing petals. Eggs may also be found among the anthers, more or less hidden by pollen. As a general rule the egg is placed parallel with the length of the floret. The entire egg is securely attached to the plant surface with an adhesive substance.

The act of oviposition is brief. Females confined in shell vials were observed to insert the tip of the abdomen as far as possible into the space between the vial



Figs. 19-21. Injury inflicted by adult of the red clover thrips on the florets of alsike clover. 19, Normal floret; 20, Shrivelled and scarified floret; 21, Rusty-brown patches of dead tissue of the corolla.

and the cork stopper. The abdomen in the region of abdominal segments VIII and IX slowly expands, and the rounded end of the egg appears through the external opening. The female quickly drops the egg with a slight posterior undulation of the abdomen. The whole operation is usually completed in one or two seconds.

Data on the pre-oviposition period, fecundity, and rate of oviposition, were obtained from a total of 11 females at 25°C. There was a mean pre-oviposition period of 4.0 days (2.0-9.0). The total number of eggs deposited by any one female was 3 to 55, with a mean of 31.1. Six of the 11 females each laid 40 or more eggs. The rate of oviposition was variable, the mean number of eggs laid in a 24-hour period being 1.2 (0.5-2.3). Generally, a female laid one or two eggs each day for three or more days, and then missed a day or two. The greatest number laid per female in a 24-hour period was four; this did not happen often. The fecundity of females held under insectary conditions was lower than that of females in the laboratory at 25°C.

Longevity and Feeding of Adults

The mean length of life of 11 females in the laboratory at 25°C. was 29.2 days (16.0-38.0). In the insectary, the mean length of life of six females was 46.0 days (17.0-61.0).

Observations indicated that the adult thrips is an indiscriminate feeder on

the host floret. It ingests the contents of pollen grains and plant cells of the floral parts. Stems and leaves are less frequently attacked.

Its method of feeding on pollen is distinctive. It collects pollen grains with quick, alternate sweeps of the fore tarsi. The pollen is placed near or directly on the apex of the mouth-cone, and a single grain fed upon. The grain is held closely appressed to the mouth-cone without assistance from the fore tarsi. In 15 to 20 seconds the effects of the feeding become apparent. The grain collapses shortly afterwards and is then abruptly released.

Although pollen was observed to be preferred food, its importance in the physiology of the adult thrips was not investigated. It was not found necessary for maturation of the ovaries since females fed on the foliage of white clover alone produced fertile eggs. A diet of pollen alone resulted in a shorter life span and decreased activity.

Haplothrips niger was found in the nymphal stages on the following host plants in Minnesota during the summer of 1952: *Achillea millefolium* L. (yarrow), *Medicago sativa* L. (alfalfa), *Trifolium hybridum* L. (alsike clover), *T. pratense* L. (red clover), and *T. repens* L. (white clover). The thrips was also collected from *Chrysanthemum leucanthemum* L. (ox-eye daisy) at Belleville, Ontario.

Life-History

The red clover thrips overwinters as a fully developed, second-instar nymph in soil beneath the withered clover plants. The depth to which the nymphs may penetrate was not determined. In January, 1953, a small number were taken from frozen soil at a depth of approximately half an inch below the surface. Pupation occurs in late April and early May. After emergence the adult seeks nourishment and protection among the small shoots and foliage of the host plant. The adults of the overwintered generation move to the flower head before anthesis

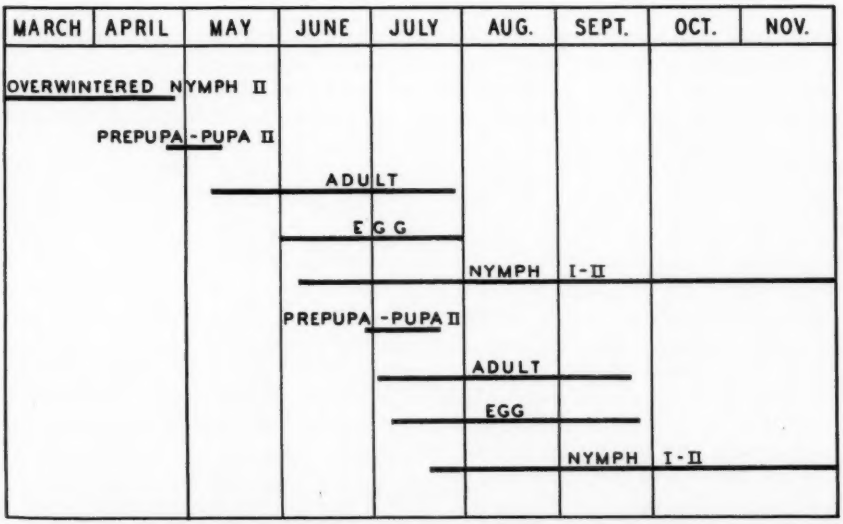


Fig. 22. Life-history of *Haplothrips niger* (Osb.) on *Trifolium repens*, based on field observations at University Farm, University of Minnesota, St. Paul, U.S.A., during the field season of 1952.

and lay their eggs among the developing florets. The life-history is represented graphically in Fig. 22.

Adults of the overwintered generation may live six to eight weeks. During this time the individuals feed and lay eggs on the host flowers. Nymphs I are found within the flower head early in June. Nymphs II become mature toward the end of the same month. Some of the Nymphs II, possibly the individuals that develop from the first eggs of the overwintered generation, pupate early in July. The period of pupation appears to be over about July 20, since no pupae were found in the field beyond that date in 1952 or 1953. The prepupae and pupae are to be found on the axis of the flower head and within florets that have set seed and become withered and brown. The adults emerging from these pupae, termed the *summer* generation, move to a flowering host. Due to the protracted period of oviposition and to diapause, immature and adult stages of both generations are found together. Since a great number of Nymphs II of the overwintered generation and all Nymphs II of the summer generation enter diapause in middle and late summer, the adults occur in greatest numbers in the spring.

By late September the adults have disappeared from the field. Nymphs II are to be found in mature flower heads until late in the fall. Development is resumed in the spring with the pupation of the overwintered Nymphs II.

Natural Enemies

Two insect predators commonly found on red clover were observed in the field and studied in the laboratory. The larvae of an undetermined species of chrysopid readily seized the adult thrips and withdrew the body fluid. A species of anthocorid, almost invariably present on host flowers, was suspected of being predacious on the thrips, especially since species of this group are known to feed in thrips, mites, and insect eggs. When placed with the thrips in the laboratory, the anthocorids made tentative movements as if to capture thrips, but no feeding was ever observed.

Summary

Field observations showed that in Minnesota, U.S.A., *Haplothrips niger* (Osb.), a pest of red and alsike clovers in North America and other parts of the world, has one complete generation per year and a partial second, and overwinters in the surface layer of soil in the second nymphal instar. Laboratory studies at 25°C. showed that reproduction is parthenogenetic, the female living 16 to 38 days (mean, 29.1) and depositing 3 to 55 eggs (mean, 31.1). Diapause generally occurs when the insect is in the second nymphal stage. When diapause does not take place, at 25°C. development from egg to adult is completed in approximately 24 days. All the life stages are described and illustrated. Details of the chaetotaxy of the nymphal instars are shown.

Acknowledgments

The authors wish to express their appreciation to the following, who gave invaluable assistance in the taxonomic problems of the study: Miss Kellie O'Neill, Division of Insect Identification, U.S. Department of Agriculture, Washington, D.C.; Dr. Guy D. Morison, North of Scotland College of Agriculture, Aberdeen; and Dr. H. Priesner, Fouad I Univérsity, Cairo.

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Larval Description of *Acanthocinus pusillus* Kby. (Coleoptera: Cerambycidae)[1]

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Craighead (1923) described the larvae of four North American species of *Acanthocinus* and constructed a key for their separation; two of these, *A. nodosus* (Fab.) and *A. obsoletus* (Oliv.), occur in the eastern half of the continent. During recent studies of cerambycids infesting fire-killed pine in central Ontario, another species, *A. pusillus* Kby., was encountered in large numbers, but the larvae could not be identified because of the lack of a published larval description. Larvae were eventually reared from known parent adults, and, since wood-boring Coleoptera are most frequently encountered in immature stages, the following description has been prepared.

Form: Elongate, sub-cylindrical, body tapering to sixth abdominal segment, last three segments wider; integument smooth, shining, sparsely clothed with short, fine hairs.

Head: Depressed, small in relation to the size of body, anterior margin deeply pigmented; one pair of indistinct ocelli. Labrum rounded anteriorly, notched shallowly at the apex; mandible strong, short, less than twice the basal width in length, cutting edge obliquely truncate. Antennal ring bisected by frontal suture (Fig. 1). Ventral mouth parts well sclerotized, anterior edge of hypostoma slightly curved; gula not evident, a pale median cleavage line present; last joint of maxillary palpus about as long as second, shorter than last labial, first labial twice as long as last; four setae on mentum (Fig. 2).

Thorax: Prothorax tapering sharply anteriorly, anterior half of pronotum shining, with a transverse row of fine hairs, posterior half velvety asperate except for a number of glabrous spots, and bearing a pair of lateral longitudinal furrows (Fig. 1); presternum rather densely beset with short hairs; posterior portion of eusternum and the sternellum shining. Mesonotum shining except for anterior portion; metanotum, mesosternum, and metasternum with velvety pubescence, marked by one transverse and two lateral furrows.

Abdomen: Ambulatory ampullae finely asperate, divided by a deep median furrow, each half bearing a crooked, T-shaped furrow (Fig. 3). Epipleurum strongly protuberant only on last three segments; pleural tubercles oval, bearing sclerotized pits at each end; spiracles circular (Fig. 4).

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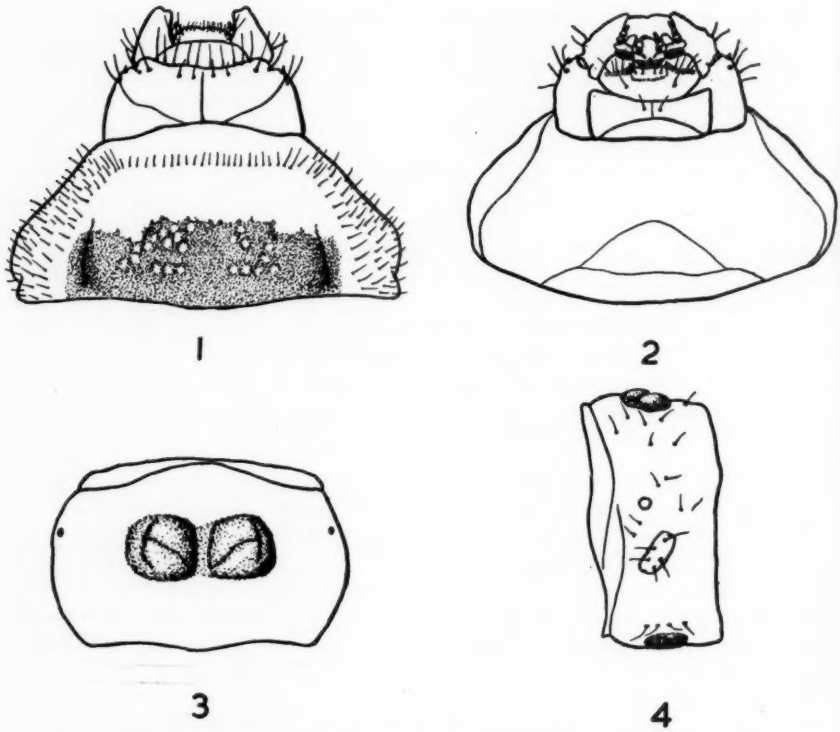

Fig. 1. Head and prothorax, dorsal aspect. 2. Head and prothorax, ventral aspect. 3. Abdominal tergum, showing dorsal ampulla. 4. Abdminal segment, lateral aspect.

The larva of *A. pusillus* may be distinguished from those of the other four North American species described by Craighead by its short, strong mandible, and the bisection of the antennal ring by the frontal suture. It differs from the European species, *A. aedilis* (L.), as described by Duffy (1953), in having only one seta and no rugose area on each side of the pale median cleavage line on the gular area.

A. pusillus has been found infesting dead or dying white, red, and jack pine trees in central Ontario, white pine apparently being preferred. The entire larval period is spent in feeding on the phloem tissue, with pupation taking place in the bark or outer sapwood. Normally, the insect completes development in one year, the adult beetles emerging through an oval hole chewed in the bark.

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On the Identity of the Gunthorp Types (Chilopoda: Geophilomorpha: Geophilidae)

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In 1913 Horace Gunthorp published his master's thesis, an annotated roster of the virtually unknown myriapod fauna of Kansas. At that time he reported the presence in the state of fourteen millipede and fifteen centipede species and so endeavoured to augment the pioneer work previously undertaken by F. W. Cragin in 1885.

Among the fifteen chilopods recorded in the 1913 paper were three new species, *Geophilus dolichocephalus, Arenophilus osborni,* and *Lithobius kansensis* —all names which have gone nearly unnoticed in subsequent publications dealing with the North American fauna.

The typical series upon which the new names were based were generously placed in my hands by Dr. A. B. Leonard of the Department of Zoology of the University of Kansas at Lawrence. The present paper is the first of a series of two that will present my views on the status of the Gunthorp types and that will redescribe them invoking characters which seem significant today.

All of the typical specimens were housed in a formalin mixture upon arrival and gave every evidence of having been so preserved for years, perhaps since the time of their collection in 1911. This would account for their brittle, distorted condition. As a consequence, the following discussion cannot deal adequately with details of sculpturing, pilosity, or color, features which have been distorted or obliterated over the years.

Relative to *dolichocephalus,* the species treated here, I have selected as lectotype the largest specimen of the lot, evidently the one that Gunthorp figured in the original description (see Gunthorp's figures 4-6).

Parawatophilus, new subgenus

Genotype: *Geophilus dolichocephalus* Gunthorp, 1913 [=*Watophilus* (*Parawatophilus*) *dolichocephalus* (Gunthorp)]. Monobasic and by present designation. The genotype of the nominate subgenus is *Watophilus alabamae* Chamberlin 1912(a): monobasic and by original designation.

The genotype of the new subgenus differs from previously known forms referable to the nominate subgenus in lacking inner and outer distal projections on the first and second articles of the second maxillae (see figure 1). At most *dolichocephalus* shows an obscure, low bulge on the inner distal corner of the second maxillary first article. In addition the virtual contiguity of the labral side-pieces may eventually be shown to be a signicant morphological departure from the condition ascribed to the labra of the other members of the genus, *i.e.* wherein the midpiece is exposed. Like *laetus,* 1912(b), *alabamae,* 1912(a), *errans,* 1912(b), and *utus,* 1928, all described by Chamberlin, Gunthorp's species has the distinctive tuberculate ultimate pretarsus and lacks ventral pore fields.

On the basis of the number of leg-pairs the present form is apparently most closely allied to *Watophilus utus* Chamberlin, 1928, collected in San Juan county, Utah. But *utus* is said to have an exposed labral midpiece, and its coxopleural pores are reputedly few in number and restricted to the coxopleural periphery. Although mention was not made of the second maxillary telopodite, presumably it conforms with the typical condition evidenced in the species' (nominate) congeners. If future studies should show *utus* and *dolichocephalus* to be con-

specific, the Chamberlin species would of course fall as a junior synonym of *dolichocephalus*.

***Watophilus (Parawatophilus) dolichocephalus* (Gunthorp)**

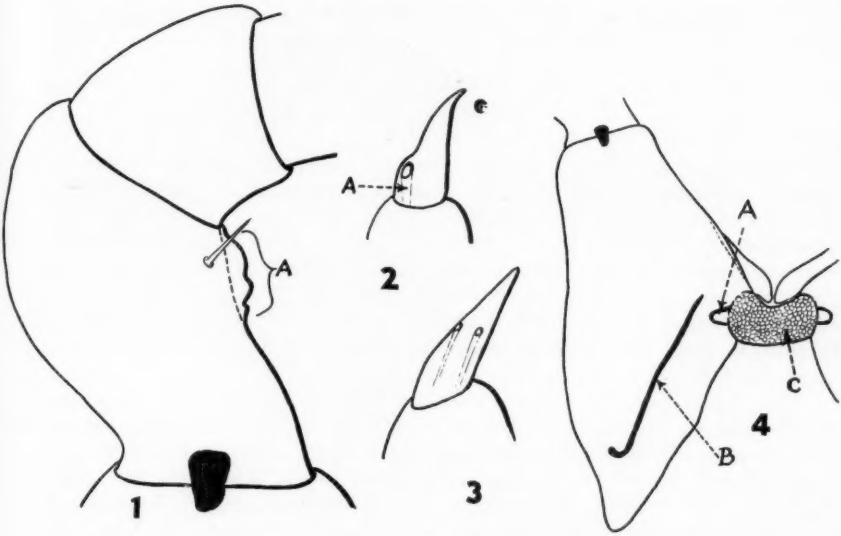
Lectotype: ♀, Cowley county, Kansas. March 1911. (Horace Gunthorp), in the collection of the University of Kansas; number 162.

General Habitus: total length 43 mm.; posterior one-half to one-third of body gradually attenuate; color (according to Gunthorp) head dark orange, body light orange, legs yellow. Antennae: articles one through six sparsely clothed with long setae; articles seven through fourteen with numerous short setae. Cephalic Plate: length to width 1.6:1; frontal suture apparently absent; anterior margin gently bowed forward, posterior margin rounded, whole plate slightly narrowing posteriorly (see Gunthorp's figure 6). Clypeus: clypeal area distinctly more finely areolate than surrounding region, the first merging insensibly into the second; clypeal setae 1+0, 1+0, 4+6, 1+1; an extensive clypeal consolidated area immediately anterior to each labral side-piece. Labrum: side-pieces medially virtually contiguous, overlapping the midpiece; entire labral margin fringed with numerous long hyaline fimbriae. First Maxillae: telepodite distinctly bipartite, the proximal article giving rise to a long robust lappet; syncoxosternum medially with a faint longitudinal streak of fine translucent areolation (the two halves in no sense actually divided, however), each anterior corner with a long robust lappet. Second Maxillae: isthmus narrow, finely areolate, colorless (figure 4,C); each half with a conspicuous elongate sclerotized ridge or *statumen* (new term) (figure 4,B); telopodite first article without outer distal protuberance, inner distal protuberance appears as an obscure low bulge and easily escapes detection (figure 1,A); second article without protuberances; apical claw long and thin (figure 3), not short and robust as in *alabamae* (figure 2). Prosternum: without trace of chitin-lines; coxopleural sutures running essentially parallel to outer prosternal margin, terminating slightly posterior to prosternal anterior margin. Prehensors: when closed, attaining level of third antennal article; each article with a dark nodule (denticle), those of the tarsungula and trochanteroprefemur larger than those of intervening articles; proximal article with an additional low prominence proximad of the disto-ectal nodule.

Tergites: as Gunthorp suggests, anteriorly prominently bisulcate, posteriorly shallowly bisulcate. Legs: clothed sparsely with long pale setae; 63 pairs.

Sternites: anterior sternites deeply, the more posterior sternite shallowly longitudinally sulcate; definitely without pore fields, apparently without pores; without carpophagous-structures. Ultimate Pedal Segment: sternite trapezoidal, posterior margin truncate and distinctly narrower than anterior margin; each coxopleuron somewhat inflated and pierced with some twenty relatively large pigmented pores (see Gunthorp's essentially accurate representation in his figure 4); each leg long and thin, sparsely clothed with long pale setae; tarsus bipartite; pretarsus present as a minute finely setose tubercle, not unguiform.

The Paratypical Series. The paratypical series consists of seven whole specimens plus a number of fragments that definitely seem conspecific with the former. Two of the whole specimens are so small, so tightly coiled and so brittle that, to preclude the danger of irreparable damage, no more than a superficial examination could be undertaken. Discounting these and the fragments, the paratypical series amounts to five specimens that can be examined. Their study shows them to be in agreement in all significant particulars with the lectotype, allowing the usual predictable variation expected on the basis of sex, size, and age. The members of the usable paratypical series show the following leg-pair



1. *W.* (*P.*) *dolichocephalus* (Gunth.). Second maxillary right telopodite, first two articles. A, obscure low bulge, evidently homologous with well-developed counterparts in members of the nominate subgenus.
2. *W.* (*W.*) *alabamae* Chamberlin. Second maxillary apical claw. A, an apparent pore-canal system.
3. *W.* (*P.*) *dolichocephalus* (Gunth.). Second maxillary apical claw.
4. *W.* (*P.*) *dolichocephalus* (Gunth.). Second maxillae, right half and isthmus. A, pore opening; B, longitudinal pigmented thickening or *statumen* (new term); C, intermaxillary isthmus.

frequencies: 69, 2 ♀ ♀, 1 ♂; 65, 1 ♀, 1 ♂. The lowest count of all of the specimens is that of the lectotype, a female with only 63 pairs of legs.

Finally, note should be made of the fact that in the original description Gunthorp cited both Bourbon and Cowley counties as the type localities, but the (original?) vial label mentions only Cowley county.

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Larvae of the Nearctic Species of *Anoplonyx* (Tenthredinidae, Hymenoptera)[1]

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Considerable confusion exists concerning the identification of larvae of the genus *Anoplonyx* in North America. Larvae of two species collected in Eastern Canada have been generally identified as one species, *A. laricis* (Marlatt). A published larval description of the other species, *A. canadensis* Harrington, is not available. Keen's (1938) published descriptions of the western species (*A. occidens* Ross and *A. laricivorus* Rohwer and Middleton) apparently had the wrong association between larvae and adults. This study was undertaken to provide more detailed larval descriptions of nearctic species of *Anoplonyx* as listed by Ross (1951).

According to Dyar (1897), the first larval description of *Anoplonyx* in North America was made by Packard (1890); he called it *Selandria*? species, in his section on insects injurious to larch or tamarack. This species has also been described as *Hemichroa laricis* Marlatt by Dyar, and as *Marlattia laricis* (Marlatt) by Yuasa (1922). Their descriptions agree closely with that of *A. laricis* (Marlatt), which was placed as a synonym of *A. luteipes* (Cresson) by Ross (1951), but they failed to mention the presence of an epipleural stripe.

The terminology used will be that proposed by Middleton (1921) and Yuasa (1922).

Larval Characteristics of the Genus

Larvae are tapered caudad with thorax larger than abdomen, producing a humped appearance. Larval length of the four species ranges from 10-14 mm., with larvae of *A. occidens* being longer and more robust; head brown and reticulate (early instars of *A. canadensis* have a dark reddish-brown head), with a lighter coloured area around the frons and central part of labrum (Fig. 1); ocularia black; labrum slightly emarginate; antennae 4-segmented, segment 1 small with a light coloured spot, segments 2 and 3 may or may not be complete ring-like structures with 2 light coloured spots, segment 4 mammillate (Fig. 7 and 8); left and right mandibles with dentes as illustrated in Fig. 6; cervical furrow present; setae on head sparse and short, except near ocelli and antennae.

Dorsum of body granulate; thoracic legs have 5 segments; uropods present on abdominal segments 2-7 with a rudimentary uropod on the eighth; postpedes reduced and divided on ventrum; eversible glands present between uropods; third abdominal segment with 5 annulets ((A, B, C^1, C^2, and D) (Fig. 2, 3, 4, and 5)); setae on body sparse, minute, and readily discernible only on *A. occidens* and at the extreme caudal end of the other species; a single seta generally present on the supraspiracular area of A, setae generally present on dorsum and supraspiracular area of B and C^2, postspiracular area, preepipleurite, postepipleurite,

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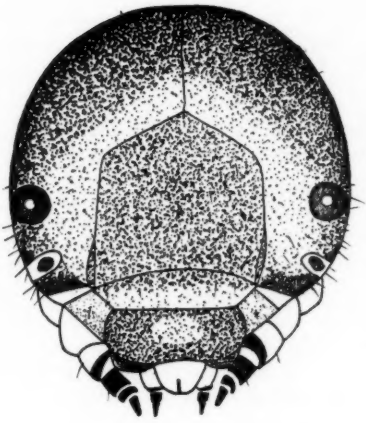
Fig. 1: cephalic view of head capsule. *A. canadensis* Harrington. Fig. 2, 3, 4, and 5: lateral view of third abdominal segment. 2. *A. canadensis* Harrington. 3. *A. laricivorus* Rohwer and Middleton. 4. *A. occidens* Ross. 5. *A. luteipes* (Cresson). Fig. 6: ventral view of mandible. *A. occidens* Ross. Fig. 7 and 8: dorsal view of antennae. 7. *A. canadensis* Harrington. 8. *A. luteipes* (Cresson).



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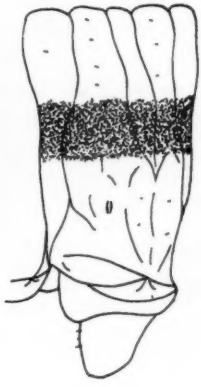

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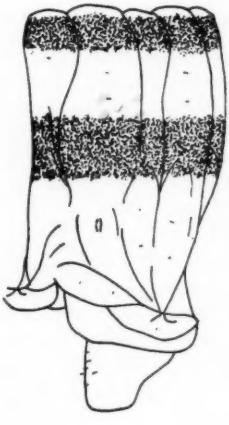

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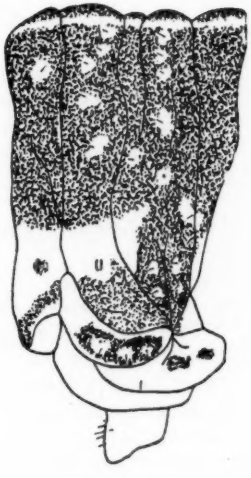

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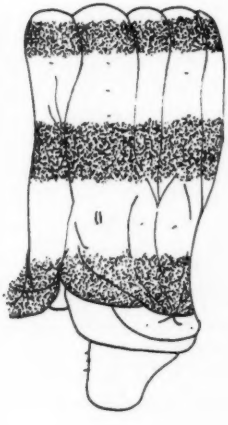

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and cephalic side of uropod; glandubae microscopic and indistinct, but appear to be slightly stalked and present on C^2, postspiracular area, preepipleurite and postepipleurite; spiracles not winged.

Cocoons have a double wall as described by Wong (1951) and are cylindrical in shape.

Key to the Late Feeding Stages of *Anoplonyx* Larvae in Canada

1. Larvae grey-black in colour; with narrow green middorsal stripe; light coloured setal areas on body (Fig. 4) ..... *A. occidens* Ross
   Larvae green in colour; without middorsal stripe or light coloured setal areas 2
2. Larvae without olive addorsal stripe with only olive supraspiracular stripe (Fig. 2); dark brown patch on lower side of head (Fig. 1); segments of antennae compact (Fig. 7) ..... *A. canadensis* Harrington
   Larvae with olive addorsal stripe and supraspiracular stripe (Fig. 3 and 5); without dark brown patch on lower side of head; segments of antennae not compact (Fig. 8) 3
3. Larvae with an olive epipleural stripe (Fig. 5); Eastern Canada ..... *A. luteipes* (Cresson)
   Larvae without an olive epipleural stripe (Fig. 3); British Columbia ..... *A. laricivorus* Rohwer and Middleton

Biological Notes

Complete life histories have not been worked out for any of the nearctic species. In Europe, Crooke (1953), working with *A. destructor* Benson, observed 5 instars. He was unable to find any males of *A. destructor* in Britain, and he concluded that it appears to be entirely parthenogenetic. In the course of rearing *Anoplonyx* larvae from across Canada both male and female adults of all species were obtained.

Members of this genus feed on the foliage of *Larix*, and are solitary feeders. Females deposit oval shaped eggs in the needles. Under laboratory conditions usually one egg was deposited per needle. *A. occidens* deposited up to three eggs per needle. When more than one egg was laid, they were usually separated by a distance equal to the length of an egg. Under laboratory conditions eggs hatched in 4-6 days. The young larvae fed by notching the needles; the older larvae usually consumed the entire needles. When not feeding the larvae lay flat on the needle.

In the field, larvae of all species except *A. canadensis* were collected during the period from late June to late August. The larvae of *A. canadensis* were collected from late August to early September. When feeding is complete, the larvae of this genus enter the duff and mineral soil to construct double-walled cocoons. Litter and soil are incorporated into the outer wall. Under laboratory conditions cocooning took place from late July to early September. Adults emerge in the following spring, generally during May. *A. canadensis* emerges later than the others, from late May to early June.

There are no records of serious damage caused by species of *Anoplonyx* in Canada. In the United States, Keen (1938) reported an outbreak of *A. occidens* and *A. laricivorus* throughout northern Idaho and western Montana in 1921, but it disappeared in 1922.

During the course of rearing *Anoplonyx* larvae at Winnipeg, a number of parasites and diseases were found. The diseases, *Isaria farinosa* (Dicks) and *Beauveria bassiana* (Bals.) were obtained from *Anoplonyx luteipes*. The parasites are listed below.

Anoplonyx luteipes (Cress.)
Ichneumonidae
Erromenus punctulatus Holmg.
Erromenus sp.
Mesoleius sp.

Anoplonyx laricivorus Roh. and Midd.
Ichneumonidae
Hypamblys albopictus (Grav.)
Itoplectis obesus Cush.

Tachinidae
Bessa harveyi (Tnsd.)
Anoplonyx occidens Ross
Ichneumonidae
Rhorus (*Cyphanza*) sp.
Braconidae
Ichneutes sp.
Anoplonyx canadensis Harr.
Ichneumonidae
Mesochorus sp.
Mesoleius sp.

Distribution in Canada

The Canadian species of *Anoplonyx* indigenous to British Columbia (*A. occidens* and *A. laricivorus*) are not found east of the continental divide. *A. luteipes* is distributed from Alberta to Newfoundland and *A. canadensis* has been collected from Saskatchewan to Newfoundland. McGuffin[1] reported that no specimens of *A. canadensis* have been collected in Alberta. Larvae collected about 20 miles south and 50 miles east of Fort Nelson on the Alcan Highway in British Columbia resemble *A. canadensis* in colour and markings and appear to be the same species. *A. luteipes* is the most common species collected east of the Rocky Mountains and *A. occidens* the most common species in British Columbia.

Acknowledgments

Material for the present study was provided by several units of the Canadian Forest Insect Survey. Dr. D. A. Ross, Vernon, B.C., and Mr. R. S. Forbes, Fredericton, N.B., were especially helpful in sending the author material from the Pacific and Atlantic coasts respectively. Dr. R. Lambert, Systematic Unit, Division of Entomology, Ottawa, identified the adults reared from the larvae and reviewed this manuscript. The parasites were identified by Messrs. G. S. Walley and J. F. McAlpine of the Systematic Unit. The diseases were identified by J. C. E. Melvin, Forest Biology Laboratory, Winnipeg, and confirmed by the Laboratory of Insect Pathology, Sault Ste. Marie, Ontario.

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[1]McGuffin, W. C. Personal communication. 1954.

(Received February 9, 1955)

FIRST ANNOUNCEMENT

TENTH INTERNATIONAL CONGRESS OF ENTOMOLOGY

MONTREAL, CANADA, 1956

President, Dr. W. R. Thompson
Secretary, Mr. J. A. Downes
Associate Secretary, Dr. W. G. Friend
Treasurer, Mr. A. B. Baird

The Tenth International Congress of Entomology will be held in Montreal from 17 to 25 August, 1956. The meetings will be held at McGill University and the University of Montreal.

SECTIONS

The Sections of the Congress have been arranged provisionally as follows:

1. Systematics
2. Morphology and Anatomy
3. Physiology
4. Behaviour
5. Ecology
6. Geographical Distribution
7. Genetics and Biometrics
8. Palæontology
9. Arachnida and other land Arthropods
10. Agricultural Entomology
11. Forest Entomology
12. Medical and Veterinary Entomology
13. Stored Products Entomology
14. Biological Control
15. Apiculture

These sections will, however, be interpreted so as to cover the whole range of entomological science. Symposia will be arranged in many of the sections. Further announcements will be made later.

EXCURSIONS

A visit to the Science Service Laboratories, Ottawa, and certain short excursions will take place during the Congress. Following the Congress, tours to a number of more distant laboratories and excursions for collecting will be possible.

A wide choice of accommodation in hotels, student residences, and guest houses will be available at prices ranging from $2 to $10 a night. Camping facilities are available at Macdonald College, about 25 miles from Montreal.

CONGRESS MEMBERSHIP

The Congress fee will be $15, with a reduction for accompanying members and student members. A charge will also be made for some of the excursions.

There will probably be limited dollar funds available for small grants-in-aid for living expenses for members who are not otherwise provided for. Such members are invited, when replying to this announcement, to ask for the form of application. Applications from members sponsored by governmental or commercial organizations, or from those residing in North America, cannot be entertained.

MEMBERSHIP

Those wishing to receive further information with a view to attending the Congress should notify the Secretary as soon as possible. They will then receive the application forms and a booklet giving more particulars.

These papers can be sent only to those who give the notification requested.

Those who would like to receive a personal invitation are requested to apply to the Secretary.

J. A. DOWNES, *Secretary*,
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Science Service Building,
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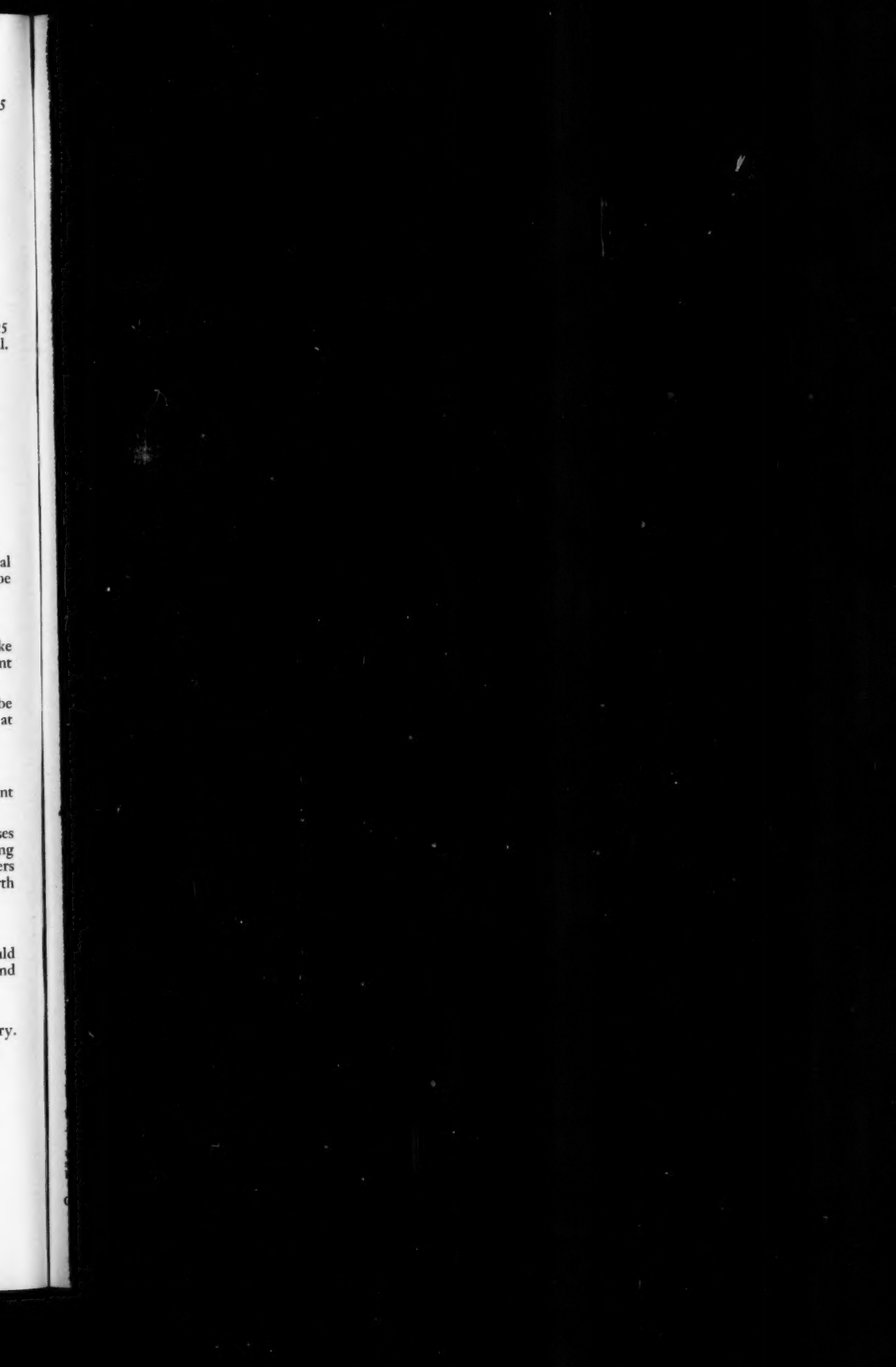
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